Vol. 18

182

Th

BRIG. G
WILDER D.
JOHN J. C
ALLERTON
MAJOR A.
W. J. HU
HARRY P.

GEORGE S.

Scientific

The Co

Electrol

Slab Det
Inter

Streams

A Nation

Notes fr
The

Notes fr
Com
Ve
Hu

The Fra
Ba
Co
Ba
Ha
Li

Book Re

Publicat

Current

Index . .

Announc

THE FRA
FIVE C

Entered at the P

HOWSON & HOWSON

SOLICITORS OF PATENTS

WEST END BUILDING, 32 S. BROAD STREET
PHILADELPHIA

NEW YORK
LIBERTY TOWER, 66 LIBERTY STREET
COR. NASSAU

WASHINGTON
910 F STREET

The Underwood Typewriter

By right of merit, first in its field.

Holder—Franklin Institute Award Elliott Cresson Gold Medal for Ingenuity, Skill and Perfection of Workmanship.

Holder—For Ten Years International Typewriter Trophy awarded for Speed, Accuracy, Stability.

"The Machine You Will Eventually Buy"

Journal
of
The Franklin Institute
Devoted to Science and the Mechanic Arts

Vol. 182 **DECEMBER, 1916** No. 6

SCIENTIFIC RESEARCH IN RELATION TO THE INDUSTRIES.*

BY

CHARLES P. STEINMETZ, A.M., PH.D.,

Chief Consulting Engineer, General Electric Company, Schenectady, N. Y.
Member of the Institute.

INDUSTRY, and with it all our modern civilization, depends on engineering. Engineering however is nothing but applied science, and science thus is the foundation, scientific research the ultimate means which have created our civilization. Through ages, the chief homes of scientific research have been the universities and other educational institutions. During the last generation however, the industrial development has been so rapid, and the demand for the results of scientific research so great and urgent, that the universities have not been able to supply it, and the industries, especially the more powerfully organized modern industries, as electrical engineering, chemistry etc., had to enter the field of scientific research. The country's educational institutions did not advance in fostering scientific research to the same degree as the industries advanced, and many universities and educational institutions rather retrograded in scientific research, became submerged in a false commercialism which figured the output of the college in student hours per professor, judged effi-

* Presented at a joint meeting of the Institute and the Philadelphia Section, American Institute of Electrical Engineers held Wednesday, October 18, 1916.

[NOTE.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.]

Copyright, 1916, by THE FRANKLIN INSTITUTE

ciency by the percentage of students graduated, and altogether too often wasted the university's best assets, its professors. Thus we find in our colleges men who had shown themselves capable as investigators to do scientific research work of the highest order, overloaded with educational or administrative routine, and deprived of the time for research work. Private industries rarely commit such crimes of wasting men on work inferior to that which they can do industrial efficiency forbids it.

Thus, when with the advance of industry a more rapid extension of our scientific knowledge was demanded, than given by the educational research institutions, scientific research laboratories were established in the industries. Some of them very soon showed their ability of producing scientific work of high character. As illustration I may mention, how an entire new branch of chemistry, the chemistry of the free atom, has resulted from the work of Langmuir in the Electrochemical Research Laboratory of the General Electric Company, and has been communicated to the literature by numerous papers.

However, these scientific research laboratories of the industry represent only a part, often the minor part of the research work done within the industry, and in many places throughout the industrial organization opportunity is afforded for the right men to carry out scientific research. Thus in the materials testing laboratories of our industrial corporations, in their standardizing laboratories, their apparatus testing departments, development sections and laboratories, etc., research work is being carried out, and as a rule is encouraged by the corporations.

Referring only to the field of electrophysics, most of our knowledge of the phenomena of electric waves and impulses in circuits, of magnetism, of dielectric phenomena etc., has come from this source.

When speaking of industrial research laboratories, we must not forget the private testing laboratories, development laboratories etc., which have been established and which to the smaller industrial organization take the same position, and do the same work, as their own laboratories to the great industrial corporations.

Theoretically, there is a limitation imposed on scientific research work in industrial establishments: It should be of such character, that it may lead to results which are industrially useful. In reality however, this is no limitation at all, but there is no

scientific investigation, however remote from industrial requirements, which might not possibly lead to industrially useful developments: and obviously no immediate or direct usefulness is expected: any investigation offering a definite prospect of industrial utility, is not scientific research, but is industrial development or design. Experience indeed has shown, that it is rare that sooner or later some industrially valuable results do not follow, no matter how abstruse and remote from apparent utility a scientific investigation may appear, and any scientific research whatsoever thus is industrially justified.

To illustrate, when by the Consulting Engineering Laboratory of the General Electric Company, research work was undertaken on the electrostatic corona and in general on the dielectric phenomena in the air, no immediate or direct benefit could be seen for the industrial company which financed the work, but it was justified by the consideration that a greater knowledge of these phenomena may extend the economic limits of long distance power transmission and thereby increase the industrial demand for transmission apparatus. Nevertheless, before the research was completed—if research can ever be considered completed—it had led to a redesign of practically all high voltage transmission apparatus and thus proven essentially valuable in industrial design.

Some research work can be carried out more efficiently by educational institutions, others by the industry. In general, for industrial research, better facilities in materials and in power are available, but high class skilled labor, of investigators and research men, such as available in university research by the graduate students, is expensive in the industry. Thus researches requiring little in facilities, but a large amount of time and attention of research men, are especially adapted to educational laboratories, while investigations requiring large amounts of material or of power rather than time of the investigators, are specifically adapted to the industry, and often beyond the facilities of the educational institution. Efficiency thus should require a division of research between educational and industrial laboratories in accordance with their facilities, and where this is done, the results are splendid. Thus for instance, the phenomena of the dielectric field beyond the elastic limit, or in other words those of the disruptive effects in air and other dielectrics under high electric stress, were almost entirely unknown a very few years ago, and it was

even unknown whether there is a definite dielectric strength of materials, analogous to the mechanical strength. This field has been very completely cleared up, and a comprehensive knowledge of the phenomena of the dielectric field gained, not only under steady stress, but also under oscillating stress, and under the transient stress of sudden electric blows or impulses, ranging down to the time measured by micro-seconds, as the result largely of the work of an industrial research laboratory—The Consulting Engineering Laboratory of the General Electric Company under Mr. F. W. Peek—and an educational laboratory—Johns Hopkins University under Professor Whitehead—both laboratories working independently and devoting their attention to those subjects, for which they are specifically fitted, though naturally often overlapping and checking each other.

Unfortunately, this limitation of research work in accordance with the available facilities is not always realized, and especially educational institutions not infrequently attempt research work, for which industrial laboratories are far better fitted, while research work for which the educational institution is well fitted, which the industry needs but can not economically undertake, is left undone. It is usually the desire to "do something of industrial value" which leads universities to undertake investigations on railroading and similar subjects, in which the probability of adding something material to our knowledge is extremely remote, or to undertake investigations on industrial iron alloys in competition with the vastly greater and more efficient research of industrial laboratories in this field of magnetism, while all other magnetic research is largely neglected, our knowledge on the phenomena of magnetism therefore still very unsatisfactory, and it is obvious that a material advance can be expected only from a comprehensive study of the entire field of magnetism, and the little investigated non-ferrous magnetic materials thus would be the ones most requiring study.

The closer relation of industrial research laboratories to the engineering practice leads to a tendency which in general may be expressed by saying, that in the results of industrial research, the probable error is greater, but the possibility of a constant error less than in educational research. In any investigation, typical conditions are selected. As these conditions naturally never can be perfect, two ways of procedure are feasible: either to in-

vestigate the errors and disturbing factors, and correct for them or to select the condition of experiment so that the disturbing factors are negligible, for instance experiment on a large scale. The latter method can not give as high accuracy as the former, but the former method, while theoretically more accurate, may give a constant error, possibly of hundreds of per cent., if some of the assumptions on which the corrections are based, are not completely justified. Industrial research leans towards the first method, as giving results which are safer in reliability, even if somewhat less accurate, while educational research leans towards the method of applying corrections. As illustration, in magnetic investigations, the effect of joints in the magnetic circuit, of joke, etc., may be determined and corrections for it applied or such a magnetic circuit may be chosen, that the effect of joints etc. is negligible, and can be neglected, or taken care of by a correction which is so small that its accuracy is not material.

In industrial research, the liability exists of limiting the work into such a narrow field, that it has little general scientific value: for instance, to determine the hysteresis loss in a magnetic material, without determining the magnetization curve. In educational research inversely there is sometimes the tendency to generalize beyond the limits justified, and so draw wrong conclusions. For instance, numerous investigations have been made and conclusions drawn therefrom in treatises on "the arc," while in reality the investigation was made with the carbon arc only, applies only to this kind of arc, and as the carbon arc is not typical but rather exceptional, for most other arcs the conclusions are wrong.

As regards to the quality of the scientific research work done in industrial organizations compared with that in educational establishments, there is no material difference, but the work done in the industry, just as that done in universities, varies from scientific research of the highest quality, down to investigations which are of little, if any value, investigations crude and inaccurate or directly erroneous in premises, in method and in results and their interpretation, or investigations, which while correctly conceived and correctly made, are useless, because essential conditions have not been controlled or recorded. Still worse are those pseudo scientific investigations occasionally met, which own their conception to the desire of self-advertisement or are made for commercial or legal purposes, such as, for instance, to

give the appearance of a scientific standing to some theory which some inventor had recorded in his patents. Such work—met occasionally, though less and less frequently—in industrial as well as in educational institutions, is the one which tends to discredit scientific research in the eyes of the layman, who can not discriminate between science and pseudo science.

The essential difference between industrial and educational research however is met in their method of publication: the publication mediums of scientific research carried on in educational institutions are the scientific publications published more or less under the direction or supervision of universities, while the publication mediums of the scientific research carried on in the industry are the technical or engineering papers, and only occasionally an abstract reaches the scientific publications. Unfortunately a large number of the scientists still look on publications in the technical press as unscientific, take no cognizance of it, do not recognize it in scientific abstracts, reviews, etc., and as the result, a large and steadily increasing part of the scientific research of the country is practically lost to the scientists, is not available or easily accessible, by not being recorded, abstracted or indexed in the records of scientific progress. If for instance in the tables of physical constants, published only a few years ago, under "hysteresis" are published the losses in a Siemens cable transformer (a type which had ceased to exist a quarter of a century ago), and practically all that mass of data on magnetism, recorded in the engineering proceedings, neglected, apparently as not "scientific," it shows that there is something wrong with the attitude of those responsible for the records of science. Amongst the worst offenders in this unjustified exclusiveness are the physicists, while the chemists make a recommendable exception: In the "chemical abstracts" published by the American Chemical Society, the results of industrial research as well as those of the chemical university laboratories are recognized, and these abstracts are therefore comprehensive and valuable, which cannot be said of the abstracts of some other sciences. Possibly the reason is, because applied chemistry is chemistry just as well as theoretical chemistry, while applied physics goes under the name of engineering, and the average theoretical physicist is rather inclined not to recognize engineering as scientific. Some excuse hereof may be found in the nature of the two classes of publications, the physical science publications and

the engineering publications. The former accept for publication only scientific papers, exert a critical judgment, and the appearance in the scientific publication medium thus implies that the article, at least in the opinion of the editors, is of scientific value. This is not the case, and can not be the case with the engineering or technical publications: the technical press is the medium of all the publications of those engaged in the industry, from scientific research of the highest value, to mere commercial statements, and the appearance of an article in an engineering paper or transaction does not imply, nor intend to imply, that it is of scientific value, but the discrimination between scientific worth or otherwise, which in the scientific publications is attempted by the editors, has in the engineering press to be left to the reader or abstractor. If however, the purpose of the engineering publication is to bring all classes of industrial records, and it thus includes commercial and other articles, this is no justification to refuse recognition to scientific papers contained in the same publication, but rather makes it desirable, and indeed necessary in the interest of our nation's scientific efficiency, to find some means or organization to carry out this discrimination and make available to the scientific world at large, the scientific work contained in the annals of applied science, that is, engineering.

To conclude then: scientific research of the highest class is carried out to-day in our nation in educational institutions as well as in industrial organizations and private testing laboratories, and the scientific research work in the latter is increasing at a far greater rate than that in the former. The publication mediums of scientific research of industrial organizations are the engineering publications and transactions, and the failure, in many branches of science, of recognizing the engineering publications in the records of science, thus makes the records of science incomplete, and increasingly so, therefore seriously retards the progress of science, and with it that of applied science, that is, engineering, and as engineering is the foundation of our civilization, it constitutes a serious menace to our nation's progress.

It is therefore important that those scientists, who are engaged in keeping the records of science and making the results of scientific research available and easily accessible, should recognize all sources and records of scientific research, including those of

applied science, that is, the engineering publications, and should undertake the work reviewing the technical press as well as the purely scientific publications, judging and selecting from the former those publications which are of scientific value, and recognize them. Only then will our records of science be complete and thereby valuable.

Immediately, the question then arises, is not the keeping of records of sciences one of the most important and most valuable activities, which in the interest of our national progress could be undertaken by our national government, by the National Bureau of Standards, as the only body, which is unpartisan and unprejudiced, is by its nature in close contact and intensely interested in engineering, and at the same time has proven its scientific standing and ability of doing scientific work of the highest class, and thereby on judging on scientific work?

Tendencies in Street Lighting Practice. ANON. (*Electrical World*. vol. 68. No. 10. September 2, 1916.)—A study of data on street lighting practice, collected from more than 100 cities, ranging from metropolitan population down to 25,000 inhabitants, shows that practically all types of street illuminants formerly used are giving place to gas-filled incandescent lamps and the improved types of arc lamps. Although gas-filled lamps are very prominent among the recent installations, the number of magnetite lamps which have been recently installed is by no means small. This may be accounted for by the longer life electrodes that are now being furnished, which partly compensate for the handicap that this type of lamp suffers in competition with gas-filled united. At the same time there is evidence that increased confidence is being placed in gas-filled lamps, this being probably due to the increased lamp life which can be obtained by the development of improved methods of manufacture and improved forms of fixtures.

According to reports from various companies during the year, and from organizations, there is an increased tendency towards ornamental lighting. Generally single lamps or, at most, double-lamp posts are being adopted instead of clusters, which were popular several years ago. The introduction of gas-filled lamps has in general resulted in increasing the candlepower used rather than in decreasing the wattage. Most of the gas-filled lamps have been of the series type, but multiple units are employed in central districts.

THE CONDENSATION PUMP: AN IMPROVED FORM OF HIGH VACUUM PUMP.*

BY

IRVING LANGMUIR, PH.D.

Research Laboratory of the General Electric Company, Schenectady, N. Y.

In a recent article in the *Physical Review*[1] the writer described a new form of mercury vapor vacuum pump, which was characterized by its extreme speed and the high degree of vacuum attainable. The preceding paper was merely a preliminary announcement of the new type of pump and no attempt was made to describe more than one form of the pump. In fact it was stated that "In a subsequent paper the writer will describe in more detail other modifications of mercury vapor pumps, some of which have marked advantages in simplicity of construction and reliability of operation over that shown here."

The object of the present paper is therefore to describe these improved pumps. Before doing this, however, it will be desirable to describe the original pump.

The original type of pump is shown diagrammatically in Fig. 1.

In this device a blast of mercury vapor passes upward from the heated flask A through the tubes B and C into the condenser D. Surrounding B is an annular space E connecting through F and the trap G with the vessel to be exhausted. The tube C is enlarged into a bulb H just above the upper end of the tube B. This enlargement is surrounded by a water condenser J from which the water is removed at any desired height by means of the tube K which is connected to an aspirator. The mercury condensing in D and H returns to the flask A by means of the tubes L and M. The tube N connects to the "rough" or "backing" pump which should maintain a pressure considerably lower than the vapor pressure of the mercury in A.

This pump operated extremely satisfactorily but was rather difficult to make. Trouble was frequently experienced by some

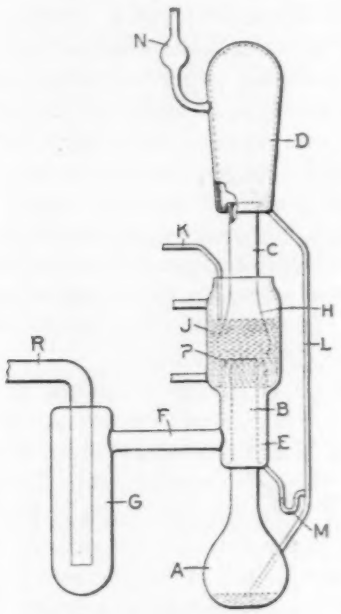
* Communicated by the author.

[1] Langmuir, Phys. Rev. **8**, 48, (1916).

liquid mercury collecting at the bottom of the annular space E. This mercury by being in contact with the hot tube B gave off vapor which produced a blast passing upwards into the annular space E. Some of this mercury vapor flowed out along the tube F and interfered with the free passage of gas from F into the pump.

This difficulty may be avoided by the construction shown in Fig. 2. A circular trough, separated from B, is provided in

FIG. 1.



First form of condensation pump.

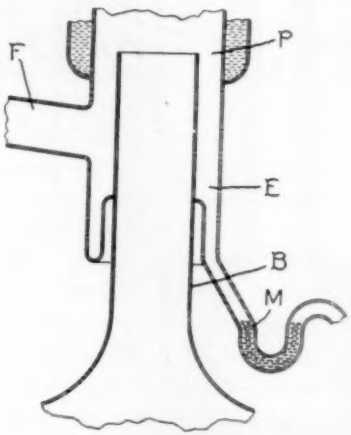
which the mercury may collect before flowing out through M. This prevents the mercury from being heated to a temperature high enough to give off troublesome quantities of vapor. In pumps of the type shown in Fig. 1 the difficulty could be easily overcome by directing a jet of air against the glass walls of the annular space E just below its junction with F. Tilting the apparatus slightly so that the mercury drained out more readily into the tube M also proved useful.

THE IMPROVED TYPE OF GLASS PUMP.

To completely avoid these difficulties the design shown in Fig. 3 was adopted. In this pump, mercury vapor from the flask *A* is carried through the thermally insulated tube *B* to the nozzle *L*. The vessel to be exhausted is connected to *R*. The gas from this vessel passes through the trap *G* and the tube *F* into the annular space *E*. At *P* this gas comes into contact with the mercury vapor blast issuing from the nozzle *L* and is thus forced *outward* and *downward* against the walls of the tube *C* and is finally driven down into the space *D* from which it escapes into the rough pump connection *N*. The mercury which condenses on the sides of the water-cooled tube *C* passes back through the tube *M* into the boiler *A*.

By this construction none of the mercury which condenses

FIG. 2.



Special construction designed to prevent overheating of the condensed mercury.

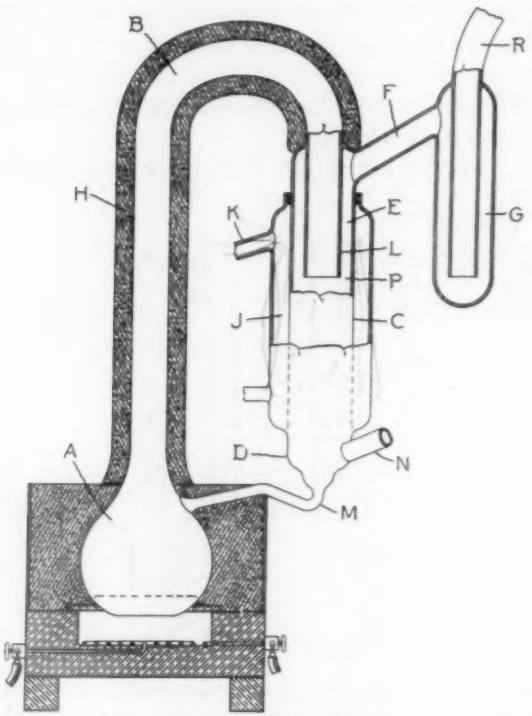
passes into the annular space *E* and thus the troublesome blast of mercury into the tube *F* is wholly avoided. The glass-blowing work on this type of pump is also much less difficult than on the earlier type.

In the pump shown in Fig. 1 a part of the mercury vapor condensed on the walls of the enlargement *H*, but the larger part passed up into the air-cooled condenser *D*. In the newer pump (Fig. 3) the enlargement of the tube *C* and the second condensing chamber are eliminated entirely. This greatly simplifies the con-

struction without materially affecting the operation of the pump. It is true that the speed of operation appears to be somewhat higher in the type containing the enlargement, but the speed of these pumps is usually so excessive even without the enlargement that a further increase in specd serves no useful purpose.

In order that the pump may functionate properly it is essential that the end of the nozzle *L* (Fig. 3) shall be located below

FIG. 3.



Improved form of condensation pump.

the level at which the water stands in the condenser *J*. In other words, the overflow tube *K* must be placed at a somewhat higher level than the lower end of the nozzle as is indicated in the figure. The other dimensions of the pump are of relative unimportance. The distance between *L* and *D* must be sufficiently great so that no perceptible quantity of gas can diffuse back against the blast of mercury vapor, and so that a large enough condensing area is furnished.

The pump may be made in any suitable size. Some have been constructed in which the tube B and the nozzle L were one and a quarter inches in diameter while in other pumps this tube was only one-quarter inch in diameter and the length of the whole pump was only about four inches. The larger the pump the greater the speed of exhaustion that may be obtained.

OPERATING CHARACTERISTICS.

In the operation of the pump the mercury boiler A is heated by either gas or electric heating so that the mercury evaporates at a moderate rate. A thermometer placed in contact with the tube B, under the heat insulation, usually reads between 100° and 120° C. when the pump is operating satisfactorily. Under these conditions the mercury in the boiler A evaporates quietly from its surface. No bubbles are formed so there is never any tendency to bumping.

Unlike Gaede's diffusion pump, there is nothing critical about the adjustment of the temperature. With an electrically-heated pump in which the nozzle L was $\frac{7}{8}$ inch in diameter, the pump began to operate satisfactorily when the heating unit delivered 220 watts. The speed of exhaustion remains practically unchanged when the heating current is increased even to a point where about 550 watts is applied.

The back pressure against which the pump will operate depends, however, upon the amount and velocity of the mercury vapor escaping from the nozzle. Thus in the case above cited, with 220 watts, the pump would not operate with a back pressure exceeding about 50 bars,[2] whereas with 550 watts, back pressures as high as 800 bars did not affect the operation of the pump.

GENERAL THEORETICAL CONSIDERATIONS REGARDING VACUUM PUMPS.

Vacuum pumps are characterized principally by three factors.

1. *Back pressure* against which the pump may be operated. This is the pressure on the exhaust side of the pump as for example at N in Fig. 3.

[2] The bar is the C. G. S. unit of pressure: one degree per sq. cm. One bar is equal to a pressure of .00075 mm. of mercury or about one millionth of an atmosphere.

2. *Speed of the Pump.*—Gaede has defined, S, the speed of a vacuum pump by the equation

$$S = \frac{V}{t} ln \frac{p_1}{p} \tag{1}$$

where t is the time required for the pump to reduce the pressure from p_1 to p in a vessel having the capacity V. The speed is thus measured in cu. cm. per second.

In the case of a piston pump this is approximately equivalent to the piston displacement per second.

3. *Degree of Vacuum Attainable.*—This is the lower limit to the pressure which may be obtained in a closed vessel connected to the pump.

For convenience we shall refer to the back pressure acting on the pump as the *exhaust pressure* while the pressure at which the gas enters the pump we shall call the *intake pressure.*

Most mechanical pumps of the piston type are built to exhaust at atmospheric pressure. But mechanical rotary pumps are frequently designed to be used in series with "rough pumps" in which case they operate with an exhaust pressure of a few hundredths of a megabar (1-5 cm. of mercury).

Newer forms of pump, such as Gaede's molecular pump and diffusion pump require still lower exhaust pressures (approximately 10–100 bars, roughly 0.01 to 0.1 mm. of mercury). Such pumps are always used in series with good mechanical pumps.

The type of mercury vapor pump shown in Fig. 3 operates with exhaust pressures ranging from 50 to 800 bars depending upon the amount of heat supplied to the boiler A.

With the exception of Gaede's molecular pump, which gives a maximum speed of about 1300 Cc. per second, mechanical high vacuum pumps have not had speeds exceeding 100 or 200 Cc. per second. Gaede's rotary mercury pump, for instance, gives a speed of about 120 Cc. per second. In nearly all cases the speed of a pump is practically independent of the exhaust pressure against which it operates unless this is raised above a certain rather critical value at which the pump ceases operating satisfactorily.

With most types of vacuum pump the degree of vacuum attainable depends to a large extent on the exhaust pressure used. This is usually due to leakage back through the pump. In the Gaede molecular pump, operating at low pressures, there is a

strict proportionality (about 50,000: 1) between the exhaust pressure and the lowest attainable intake pressure.

When a pump has lowered the pressure nearly to its limiting value the speed of *exhaustion* decreases even though the *speed of the pump* remains the same. If S is the "speed of the pump" and E is the speed of exhaustion, then for a pump with which the lowest attainable pressure is p_0 we may define E and S as follows:

$$S = V\frac{d\,ln\,(p-p_0)}{dt} = \frac{V}{p-p_0}\frac{dp}{dt} \tag{2}$$

$$E = V\frac{d\,ln\,p}{dt} = \frac{V}{p}\frac{dp}{dt}. \tag{3}$$

From these we obtain

$$E = S\left(1-\frac{p_0}{p}\right) \tag{4}$$

The "speed of the pump," S, thus defined, usually remains practically independent of the pressure. If $p_0=0$ is the limiting value of the pressure then the "speed of exhaustion" E is identical with S, the speed of the pump. In other cases the speed of exhaustion decreases as the pressure approaches p_0 and becomes zero when the limiting pressure is reached.

In operating vacuum pumps of high speed it is essential to use tubing of large diameter between the pump and the vessel to be exhausted if full advantage is to be taken of the speed of the pump. Knudsen [3] has calculated according to the kinetic theory the rate at which gases at low pressures can flow through tubing and has thoroughly checked these theoretical results by careful experiments.

Knudsen considered especially the "molecular flow" of gases through tubes at pressures so low that the collisions of the gas molecules with each other are of relatively rare occurrence as compared with the collisions between the gas molecules and the walls of the tubes. This molecular flow takes place at pressures at which the "mean free path" [4] of the molecules is large compared to the diameter of the tube.

Knudsen finds that the quantity of gas q which flows per second through a tube is given by the equation:

$$q = \frac{p_2-p_1}{W\sqrt{\rho_1}}. \tag{5}$$

[3] Ann. Physik. **28**, 76 (1909).

[4] See Dushman Gen. Electric Rev. **18**, 1042 (1915).

The quantity of gas q is measured by the product of volume and pressure. Thus

$$q = \frac{d(pV)}{dt}. \tag{6}$$

The pressure is preferably to be expressed in bars (dynes per sq. cm.). ρ_1 is the density (grams per cubic cm.) of the gas at unit pressure. From the gas law $pV=RT$ it is easily seen that the density of a gas is given by

$$\rho = \frac{pM}{RT} \tag{7}$$

where M is the molecular weight, T is the absolute temperature and R is the gas constant 83.15×10^6 ergs per degree. If we place $p=1$ we obtain

$$\rho_1 = \frac{M}{RT}. \tag{8}$$

In equation 5, W is the "resistance" which the tube offers to the flow of gas.

Knudsen finds that it is equal to

$$W = \frac{3\sqrt{\pi}}{8\sqrt{2}} \int \frac{o}{A^2}\, dl = 0.4700 \int \frac{o}{A^2}\, dl \tag{9}$$

where A is the area and o is the perimeter of the cross section of the tube. For circular tubes of diameter D and length L this becomes

$$W = \frac{6}{\sqrt{2\pi}} \frac{L}{D^3} = 2.394 \frac{L}{D^3}. \tag{10}$$

In the case of openings in thin plates Knudsen [5] gives

$$W = \frac{\sqrt{2\pi}}{A} = \frac{2.507}{A} \tag{11}$$

where A is the area of the opening.

Combining Equations 5, 8, 10 and 11 gives, for long circular tubes:

$$q_1 = \frac{\sqrt{2\pi}}{6} \sqrt{\frac{RT}{M}} \frac{D^3}{L} \left(p_2 - p_1\right) = 3809. \sqrt{\frac{T}{M}} \cdot \frac{D^3}{L} \left(p_2 - p_1\right) \tag{12}$$

and for openings in plates:

$$q_2 = \sqrt{\frac{RT}{2\pi M}} \cdot A(p_2 - p_1) = 3638. \sqrt{\frac{T}{M}} \cdot A(p_2 - p_1). \tag{13}$$

[5] Ann. Physik. **28**, 999, (1909).

These equations are strictly accurate only when the diameter of the tube or opening is very small compared to the mean free path. From Knudsen's experimental data, however, it may be shown that as long as the mean free path is not less than 0.4 of the diameter of the tube, the Equation 12 gives results accurately within about 5 per cent. With air at room temperature and at a pressure of p bars the mean free path λ is $\lambda = 8.6/p$ centimeters.

Thus in the case of a tube one centimeter in diameter the Equation 12 would be accurate within 5 per cent. for all pressures below about 21 bars.

At higher pressures the quantity of gas flowing through a tube becomes much greater than that calculated by Equation 12. For these higher pressures the flow may be calculated from the viscosity η by Poisseuille's equation:

$$q_3 = \frac{\pi}{128} \frac{D^4 p}{\eta L} (p_2 - p_1) \tag{14}$$

where q is expressed in the same units as in Equation 5. This equation is of a totally different form from those applicable at low pressures. To make this clearer let us apply these equations to the case of air at room temperature (M=28.8; T=293). The viscosity η of the air at 20° C. is $181. \times 10^{-6}$ (C. G. S. units). Equations 12, 13 and 14 thus become

$$q_1 = 12130. \frac{D^3}{L} (p_2 - p_1). \tag{12a}$$

$$q_2 = 11700\, A\, (p_2 - p_1). \tag{13a}$$

$$q_3 = 136. \frac{D^4}{L} p(p_2 - p_1). \tag{14a}$$

With a tube 1 cm. in diameter and 10 cm. long with a difference of pressure $(p_2 - p_1)$ of 1 bar we find $q_1 = 1213$. Cc. per second, and $q_3 = 13.6\, p$ Cc. per second. These represent the quantities of gas flowing through the tubes measured in terms of the volume which the gas would occupy at one bar pressure. If the volumes of gas were measured at atmospheric pressure (10^6 bars) the volumes would be one millionth as great. In other words, at very low pressures 0.001213 Cc. of gas per second would flow through the tube, while at atmospheric pressure ($p = 10^6$) 13.6 Cc. per second would flow, or more than 10,000 times as much gas.

This indicates the relatively enormous resistance which tubes offer to the passage of gases at very low pressures. It should

be noted, however, that this resistance increases as the pressure is lowered only until the state of molecular flow is reached while for lower pressures the resistance remains constant.

Let us now consider a pump having a speed S, connected to a vessel of volume V by means of a tube of diameter D and length L. What will be the rate at which the vessel is exhausted?

We will assume that the volume of the tube is negligible compared to the volume of the vessel, and that the limiting pressure for the pump is $p_0 = O$. We obtain from (2) and (6)

$$S_1 p_1 = \frac{d(pV)}{dt} = q \tag{15}$$

in which p_1 is the pressure at the pump intake and q is the quantity of gas which flows per second through the tube.

Now the pump, connected through the tube, exhausts the vessel V at a rate which is less than if the pump were directly connected to the vessel. The pump and tube together, however, constitute a system which is the equivalent of a pump of lower speed, say S_2. The rate at which gas leaves the vessel to enter the tube is thus $S_2 p_2$, where p_2 is the pressure in the vessel. This is also equal to q, the rate at which the gas passes through the tube. Thus we have

$$S_2 p_2 = q. \tag{16}$$

Solving (15) and (16) for p_1 and p_2 and substituting in (5), we obtain

$$\frac{1}{S_2} = \frac{1}{S_1} + W\sqrt{\rho_1} \tag{17}$$

The quantity $W\sqrt{\rho_1}$ represents the resistance to flow offered by the tube. The quantity $1/S_1$ must also be of the nature of a resistance: the resistance of the pump to the passage of the gas through it. That is, the pump itself may be looked upon as the equivalent of a very large, perfectly exhausted vessel connected to the apparatus to be exhausted by a tube offering a certain resistance. Knudsen has already defined the term resistance of tube by equation (9) and it is desirable to retain this definition, since resistance thus defined is a function only of the dimensions of the tube and not of the kind or temperature of the gas flowing through it.

By analogy with electrical usage, we may thus define $W\sqrt{\rho_1}$ as the "impedance" of the tube. This "impedance" will depend

on the temperature and nature of the gas in a way not entirely dissimilar to the way impedance depends on frequency. The quantity $1/S_1$ is thus to be called the " impedance " of the pump, and $1/S_2$ is the " impedance " of the pump and tubing in series.

In this way we may calculate the speed of exhaustion through complicated systems in much the same manner as the calculations are made for electrical circuits. The effect of two tubes or more in series is obtained by adding their " impedances." With tubes in parallel, their " admittances " (reciprocal of impedance) are added.

Since it is usually more convenient to deal with the speed of a pump rather than with its reciprocal, it will also be convenient to express the characteristics of tubes in terms of their " admittance." This is a quantity of the same kind as S, the speed of the pump. In general, the " admittance " of a tube or opening may be defined by

$$S = \frac{q}{p_2 - p_1}. \tag{18}$$

Thus the admittance may be calculated for any case from Equations 5, 12, 13, 14, 12*a*, 13*a*, or 14*a*, merely by placing $p_2 - p_1 = 1$. As an illustration, in the case of a tube 1 centimetre in diameter and 10 centimetres long, with air at room temperature, we find from (12*a*) and (14*a*) that the admittance of the tube is 1213 Cc. per second at low pressures and $13.6 \times p$ Cc. per second at high temperatures.

If we place such a tube in series with a high vacuum pump having a speed $S = 1213$ Cc. per second, it will evidently cut the effective speed of the pump down to one-half its former value, namely, 606 Cc. per second.

Thus, with a pump which has a speed $S = 4000$. Cc. per second (and such speeds are easily attainable with mercury vapor pumps), if we wish to use a tube which does not reduce the effective speed by more than 10 per cent., we must use a tube which has an " admittance " of at least 36,000 Cc. per second. From Equation (12*a*), we see that for a tube of this kind D^3/L must be at least 2.97. Thus if a tube 30 cm. long is to be used, the diameter must be at least 4.5 cm.

These results indicate how seriously the speed of a mercury vapor pump may be limited by the resistance of the tubing unless this is of very great size.

We have thus far considered the action of the pump in lowering the pressure in a vessel. This process can not go on indefinitely, for the pressure finally becomes lowered to a point at which the leakage of gas into the apparatus prevents a further decrease of pressure. A stationary condition is then reached.

The leak which limits the pressure may be in the pump itself, or in the vessel being exhausted. The first case is equivalent to that we have already considered, in which there is a lower limit p_0 to the pressure attainable by the pump. The rate of flow of gas into the pump is then $S_1(p_1-p_0)$.

The gas leaking into the vessel does not, in general, pass through the walls of the vessel, but is given off from the walls of the vessel or from bodies within it. Let q_2 be the rate at which such gas escapes into the vessel. Then when a stationary condition has been reached, this rate will be equal to the rate at which the gas is being removed by the pump, namely, S_2p_2 where S_2 may be calculated from the speed of the pump S_1 and the "admittance" of the connecting tube. The lowest pressure obtainable in the vessel is thus

$$p_2 = \frac{q_2}{S_2} \tag{19}$$

This equation shows that the degree of vacuum which may be reached, even by a pump for which $p_0 = o$ is limited by the speed of the pump and the size of tubing between the vessel and the pump.

Measurements of pressure by various forms of supersensitive vacuum gages[6] have shown that the rate of evolution of water vapor from glass surfaces at room temperature is such that pressures below 0.2 bar could not be obtained even when using a molecular pump ($S_2 = 870$ Cc. per second) continuously for an hour. In this case we can calculate by Equation 19 that the rate of evolution q_2 must have been 170 Cc. (of gas at 1 bar pressure) per second. This corresponds to 0.00017 Cc. of gas at atmospheric pressure per second, or 0.62 Cc. of water vapor per hour. In this case the surface of glass was about 1800 sq. cm.

After heating the glass for half an hour or more to 360°, this evolution of water vapor (at room temperature) is reduced many thousand fold, but even then, it is not avoided entirely. The

[6] See, for instance, Dushman, *Phys. Rev.*, **5**, 224 (1915).

limit to the pressure actually attainable by means of mercury vapor pumps seems to depend entirely upon this evolution of gas from the walls of the vessel and tubing, and not upon any inherent limitation in the pump itself.

Since the mercury vapor pumps are used in series with a rough pump, it is of interest to know what the speed of the rough pump should be to allow the mercury vapor pump to operate at maximum efficiency. Suppose we have a mercury vapor pump having, together with its connecting tubing, the effective speed S_2. Let this be connected to a vessel V containing gas at a pressure p_2. We have seen that the speed of mercury vapor pumps is practically independent of the exhaust pressure so long as this does not exceed a certain critical value, say p_c. Thus, to obtain the full effectiveness of the pump, it is only necessary to have a rough pump having sufficient speed (S_0) to maintain a pressure lower than p_c. Under these conditions the quantity of gas per second being delivered by the mercury vapor pump is $S_2 p_2$, and this must be equal to the quantity removed by the rough pump, namely $S_0 p_c$, from which we find

$$S_0 = \frac{p_2}{p_c} S_2. \tag{20}$$

In other words, the maximum speed of the mercury vapor pump may be realized if the speed of the rough pump is less than that of the mercury vapor pump in the ratio $p_2 : p_c$. Ordinarily, the pressure p_c for a mercury vapor pump is about 200 bars, so that if it is used to exhaust a vessel at ten bars pressure the speed of the rough pump need not exceed one-twentieth of that of the mercury vapor pump. The only advantage, then, in using a faster rough pump is that the maximum speed may still be obtained even with pressures higher than 10 bars.

In case the speed of the rough pump is not sufficient to maintain a pressure lower than p_c, then the mercury vapor pump will not operate at maximum speed, but will deliver gas to the rough pump at such a rate that the pressure on the exhaust side of the mercury vapor pump will remain substantially constant at p_c. Thus the speed of the mercury vapor pump under these conditions will vary with p_2 according to the equation

$$S_2 = \frac{p_c}{p_2} S_0.$$

THEORY OF THE OPERATION OF THE CONDENSATION PUMP.

For a number of years the writer has been convinced that the collisions between gas molecules and a solid or liquid body against which they may strike, are in general almost wholly inelastic. Each molecule which strikes a surface thus *condenses* on the surface instead of rebounding, although it may subsequently re-evaporate. This condensation takes place just as well at high temperatures as at low, but at high temperatures the re-evaporation may occur so soon that it is difficult to detect the condensation. In this case the condensed molecules constitute an adsorbed film. The condensed particles, before they re-evaporate, are held to the surface by the same kind of forces as those which hold solid bodies together. This leads to a theory of adsorption which is in excellent agreement with experimental facts.

A general review of the above theory and of the evidences supporting it, has recently been published.[7]

It was by a direct application of these ideas that the writer was led to construct a high speed mercury vapor pump.

Gaede,[8] in connection with a study of the diffusion of gases through mercury vapor at low pressures, devised a new form of high vacuum pump which he has called the "diffusion pump." Before describing the mercury vapor diffusion pump, Gaede illustrates the principles underlying the action of such pumps by means of the water vapor pump shown diagrammatically in Fig. 4. A blast of steam passes through the tube *AB*, past the porous clay diaphragm *C*. The vessel to be exhaused is connected to the tube *E* and the appendix *D* is cooled by a mixture of ether and solid carbon dioxide. Steam diffuses through the diaphragm from left to right and is condensed at *D* and is thus prevented from passing into *E*. On the other hand, the air in the vessel to be exhausted passes into *C* and *D* and diffuses through the diaphragm from right to left into the steam, where it is carried away by the blast of steam. By a pump of this type Gaede was able to obtain an X-ray vacuum in about two hours. The great fault of this pump was its slow speed.

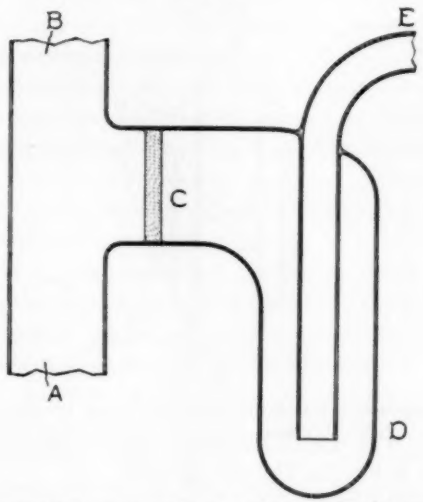
Gaede develops a simple theory of the pumps which use a clay

[7] The Evaporation, Condensation and Reflection of Molecules and the Mechanism of Adsorption. Phys. Rev. **8**, 149 (1916).

[8] Ann. Physik. **46**, 357 (1915).

diaphragm and finds that the speed can be increased either by increasing the surface of the diaphragm or by decreasing its thickness. If the thickness could be made zero, according to this simple theory, the speed would become infinite. He concludes that this equation does not apply to this case, and therefore proceeds to derive another, based on the kinetic theory. According to this theory, a porous diaphragm is equivalent to a large number of openings of dimensions comparable with the mean free path of the molecules. Gaede therefore calculates the rate at which one gas diffuses into a small hole in a thin plate out through which a second gas is escaping. In this way he finds that the first gas

FIG. 4.



Diagrammatic representation of one form of diffusion pump.

diffuses in at a maximum speed when the size of the opening is approximately equal to the mean free path of the second gas.

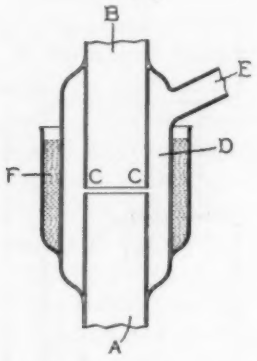
He thus determines the construction which will give a *diffusion* pump of the maximum speed. The design adopted for the mercury vapor diffusion pump is essentially that shown in Fig. 5. A blast of mercury vapor passes up through the tube *AB* past the narrow circular slit *C*. A part of the mercury vapor passes out through this slit and condenses on the water-cooled surface *D*. The gas from the vessel to be exhausted passes through *E* and *diffuses into the slit C against the escaping blast of mercury vapor*. After it enters *C* it is carried away from the slit by the

blast of mercury vapor and is thus effectively prevented from returning back through the slit.

It is evident that the speed with which the gas from E diffuses into the slit will have a maximum value for some particular width of slit. If the slit is too wide, the blast of mercury vapor escaping from it will be of such a volume that the gas molecules will not be able to diffuse appreciably against it. Gaede calculates and then shows experimentally that the maximum speed is obtained when the width of the slit is made approximately equal to the mean free path of the molecules in the mercury blast AB.

In the actual operation of the pump, Gaede finds it best to use such a pressure of mercury vapor that the maximum speed is

FIG. 5.



Diagrammatic representation of another form of diffusion pump.

obtained with a slit width of 0.012 cm. The maximum speed then obtainable is $S = 80$. Cc. per second.

Such relatively low speeds are inherent in pumps in which the gas must diffuse in through an opening against a blast of mercury vapor.

While constructing and operating a Gaede diffusion pump, it occurred to the writer that this serious limitation of speed could be removed if some other way could be found to bring the gas to be exhausted into the stream of mercury vapor. The action of a pump such as Gaede's diffusion pump really consists of two rather separate steps:

Process I. The process by which the gas enters the blast of mercury vapor.

Process II. The action of the blast of mercury vapor in

carrying the admixed gas along into a condensing chamber from which it cannot return to the vessel being exhausted.

The great advantage of the diffusion pump over all previous pumps lay in the remarkable effectiveness of the Process II. The limitations of the diffusion pump were imposed by the Process I.

Now the Process II in the diffusion pump is essentially similar to that used in commercial steam ejectors. In such ejectors, however, the Process I does not depend on diffusion, but on the lowering of pressure caused by the high velocity of the jet, in accordance with hydrodynamical principles (Bernoulli effect). The gas in an ejector is thus sucked into the jet because the *pressure in the jet is lower than that* of the gas in the vessel being exhausted. As the velocity of the mixed gases decreases in the expanding part of the ejector *C* (in Fig. 6), the pressure gradually increases up to that in the condensing chamber *D*.

Since the pressure in the jet must always be considerable, it is evident that the Bernoulli effect cannot be directly utilized to obtain a high vacuum. According to the kinetic theory also, the molecules in a jet of gas passing out into a high vacuum must spread laterally, so that there would be no tendency for a gas at low pressures to be drawn into such a blast.

In fact, it is easy to see that an ejector such as is shown in Fig. 6 could not be used to produce a high vacuum. Suppose, for instance, that a blast of mercury vapor passes through the tube *A* and escapes from *B* into the exhausted chamber *C*, and condenses at *D*. A large fraction of the atoms of mercury vapor escaping from *B* will have transverse velocity components, so that they will strike the walls of the outer tube at *K*. These will condense, but the heat liberated will cause the walls to assume a temperature comparable with that of the mercury vapor blast. The condensed mercury will therefore evaporate approximately as fast as it condenses. The atoms which evaporate are just as likely to leave the surface in a direction towards *E* as towards *C*. Therefore a large fraction of the mercury vapor which strikes the wall *K* will pass into the tube *E* and out through *F*, so that it will completely prevent the entrance into *E* of a gas at low pressures. Experiments have subsequently proved that this is exactly what happens when it is attempted to operate an ejector at very low pressure. Not only does the device fail to pump, but it is often impossible to get any gas to pass through the device, even when there is

a pressure of 100 bars or more at F and the pressure at D is held at 1 bar or less.

This reasoning indicates that the Bernoulli effect cannot be used to draw the gas into the blast (Process I). The main reason for this failure is the blast of gas which originates at K by the re-evaporation of the condensed mercury. If this re-evaporation could be prevented, the blast of gas from K to E would disappear

FIG. 6.

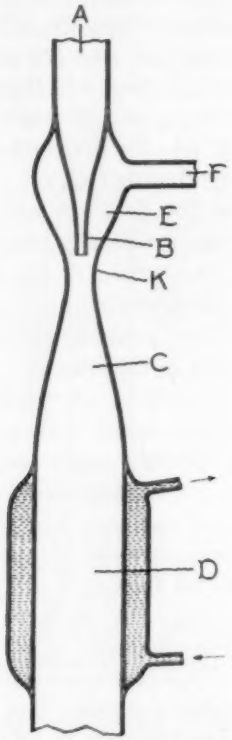


Diagram illustrating the action of an ejector.

and the gas from F would therefore meet no obstacle in passing into E and entering the stream of mercury vapor at K.

If it had been assumed that the mercury atoms striking K were *reflected* into E, then there would be no obvious means of preventing this reflection. But the work previously referred to had convinced the writer that reflection did not occur, and therefore indicated that to avoid this blast of mercury vapor into E it

would only be necessary to cool the walls of the outer tube at the point *K*.

In this way, the blast of gas into *E* is made to disappear and the gas from *F* therefore passes into *E* and towards *K*. Beyond the nozzle *B* the molecules of this gas are struck by the atoms of mercury escaping from *B* and are *forced outward* (not drawn inwards) against the walls of the outer tube at *K*. The gas molecules are then subjected to a continual bombardment from mercury atoms which have velocity components in the direction towards *C*. If the walls of the tube *C* are also water-cooled, the gas which enters at *F* is thus pushed along the walls of *C* and is finally driven into the condenser *D*.

This was the reasoning which led to the construction of the type of pump shown in Fig. 1. The very first pump constructed operated perfectly satisfactorily and gave a speed of about 1800 Cc. per second.

The action of the pump is based on radically different principles from that of the ejector. The most essential element in the operation seems to be the condensation of the mercury vapor at *K* and the maintenance of a temperature in this region so low that the condensed mercury does not re-evaporate. It is therefore suggested that pumps based on this principle should be called *Condensation Pumps*.

The distinction between the condensation pump and the ejector is clear when we realize that in the ejector there is no necessity for cooling the walls of the tube at *K*, Fig. 6, whereas the condensation pump entirely fails to operate unless this is done. Furthermore the effectiveness of the ejector depends on the flare of the tube *C* between *K* and *D*, whereas this flare is entirely unnecessary in the condensation pump. In fact, since a large portion of the mercury vapor condenses on the walls at *K*, it is rather desirable to have a *decreasing cross section* between *K* and *D*. In the form of pump shown in Fig. 1, this contraction above the point *P*, Fig. 1, was actually employed. Subsequent experiment showed that it was unnecessary to provide two condensing chambers as in Fig. 1, but that the pump could be simplified as in Fig. 3.

If this later form of pump is examined during operation, it is seen that when there is a high vacuum on the intake side of the pump, practically no condensation of mercury takes place on the walls of the condenser *C* above the level of the point *P*. In other

words, *all* the atoms of mercury vapor leaving the end of the tube *L* have downward velocity components and therefore cannot pass up above the point *P* unless they first strike some body not having the corresponding downward velocity. If, however, the walls of the condenser are allowed to become heated, then the mercury atoms from *L* collide with mercury atoms evaporating from the walls (which do not have downward velocities) and as a result of these collisions a large fraction of this mercury vapor is deflected upward into the space *E*. This prevents gas from *F* from reaching the point *P* where it might be acted on by the direct blast from *L*.

When a small flow of gas is allowed to enter through *R* so that the intake pressure is maintained at about 100 bars, it is interesting to observe that the line of demarcation below which the condensation occurs loses its sharpness, and that a considerable quantity of mercury vapor condenses above the point *P*. This is due to the collisions between the mercury atoms from *L* and the gas molecules which are driven in close to the walls of the condenser *C*.

Another interesting fact may be observed by watching the operation of the condensation pump. The greater part of the mercury vapor which escapes from *L* condenses on the walls of *C* within a couple of centimetres below the end of the nozzle *L*. This indicates that the mercury atoms radiate out from the end of *L* in all directions and show no particular tendency to continue to move in the direction in which the nozzle is pointed. This is essentially different from what happens in injectors or ejectors. It is well known that when steam escapes from a straight tube into the open air, the jet of steam continues to move in a nearly straight line for a considerable distance from the nozzle before it mixes to a large extent with the air. This effect evidently entirely disappears at very low pressures. This fact is in accordance with the kinetic theory of gases. At very low pressures the density of the mercury vapor is extremely small, whereas the viscosity of the gas is practically as great as at atmospheric pressure. The frictional effects of the walls therefore entirely predominate over the inertia effect which at higher pressures leads to the jet formation.

Some special pumps have been built to operate by a combination of the injector and condensation pump principles so that very

much higher exhaust pressures may be used. In this way it has been possible to operate a single mercury vapor pump producing as high a vacuum as the ordinary type of condensation pump, but exhausting at a pressure of about 20 mm. of mercury. Further development work will be necessary, however, before these pumps become as satisfactory as a condensation pump backed up by a mechanical pump.

CONDENSATION PUMPS BUILT OF METAL.

The condensation pump lends itself admirably to construction in metal.

One type of pump which has proved relatively simple in construction and efficient in operation is shown diagrammatically in Fig. 7. A metal cylinder *A* is provided with two openings *B* and *C*, of which *B* is connected to the backing pump and *C* is connected to the vessel to be exhausted. Inside of the cylinder is a funnel-shaped tube *F* which rests on the bottom of the cylinder *A*. Suspended from the top of the cylinder is a cup *E* inverted over the upper end of *F*. A water-jacket *J* surrounds the walls of the cylinder *A* from the level of *B* to a point somewhat above the lower edge of the cup *E*.

Mercury is placed in the cylinder as indicated at *D*. By applying heat to the bottom of the cylinder the mercury is caused to evaporate. The vapor passes up through *F* and is deflected by *E* and is thus directed downward and outward against the water-cooled walls of *A*. The gas entering *C* passes down between *A* and *E* and at *P* meets the mercury vapor blast and is thus forced down along the walls of *A* and out of the tube *B*. The mercury which condenses on the walls of *A* falls down along the lower part of the funnel *F* and returns again to *D* through small openings provided where the funnel rests upon the bottom of the cylinder.

A more detailed drawing of the pump as actually constructed is shown in Fig. 8.

Pumps of this type have been made in several different sizes. A pump in which the funnel *F* is 3 cm. in diameter and the cylinder *A* is 7 cm. in diameter gives a speed of exhaustion for air of about 3000 Cc. per second and will operate against an exhaust pressure of 200–600 bars, depending on the amount of heat supplied to the mercury. The energy consumption ranges from 100 to 500 watts.

Very small pumps have also been constructed in which the tube F is only 0.6 cm. and the cylinder A is only 2 cm. in diameter. This type of pump gives a speed of about 200 Cc. per second.

DEGREE OF VACUUM OBTAINABLE.

The condensation pump resembles Gaede's diffusion pump in that there is no definite lower limit (other than zero) below which the pressure cannot be reduced. This is readily seen from its method of operation. A lower limit could only be caused by a diffusion of gas from the exhaust side (N in Fig. 3) back against the blast of mercury vapor passing down from L. The mean free path of the atoms in this blast is of the order of magni-

FIG. 7.

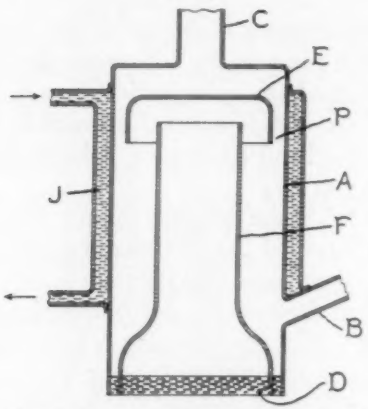


Diagram of condensation pump built of metal.

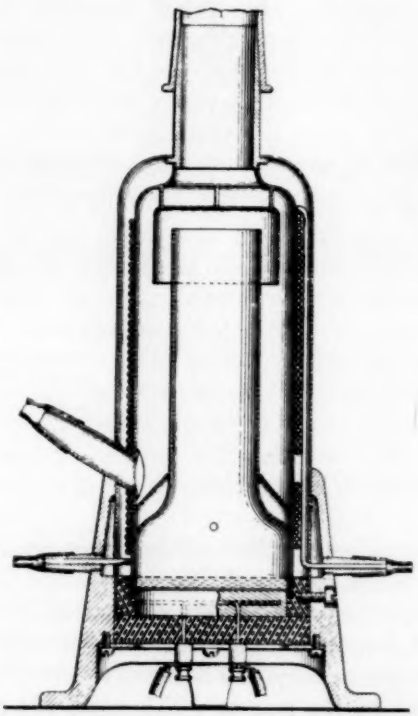
tude of a millimetre or less and the blast is moving downward with a velocity at least as great as the average molecular velocity (100 metres per second for mercury).[9]

The chance of a molecule of gas moving a distance about 4.6 times the mean free path without collision is only one in a hundred. To move twice this distance the chance is only 1 in 100^2, etc. If the mean free path were one millimetre, the chance of a molecule moving a distance of 4.6 cm. against the blast without collision would be 1 in 10^{20}. In other words, an entirely negligible chance.

[9] This is apparent when we consider that no appreciable number of atoms pass up into the space E.

However, if with any particular design of pump it should be found that gas does leak back against the blast of a vapor, it is a simple matter to increase the pressure in the blast or increase the distance against which the gas must pass back through the blast. Thus the construction adopted in Fig. 1 may be adopted where only a small part of the mercury is condensed close to the nozzle from which the vapor escapes, while the greater portion travels a considerable distance before condensing.

FIG. 8.



Condensation pump built of metal.

As a matter of fact, even in the type of pump with a single condensing chamber, such as shown in Figs. 3 and 7, there is evidence that the back diffusion is absolutely negligible under all normal operating conditions. Thus if a vessel is exhausted to .001 bar (the lowest pressure readable on a McLeod gage) while a good vacuum is maintained on the exhaust side of the pump, it is found, when the pressure on the exhaust side is gradually raised,

that the vacuum remains unchanged on the intake side until a relatively high pressure such as 200–600 bars on the exhaust side is reached. A very slight further increase in the exhaust pressure then causes a very great increase in pressure on the intake side. This result indicates that when comparatively low exhaust pressures such as 50 – 100 bars are used, the limiting pressure on the intake side, if it exists at all, must be extraordinarily low.

Of course it must be realized that the condensation pump like any mercury pump does not remove mercury vapor from the system to be exhausted. The vapor pressure of mercury at room temperature is in the neighborhood of 2 bars. By inserting a trap such as that indicated at G (in Fig. 3), between the pump and the exhausted vessel, this vapor pressure may be lowered. The following table gives the vapor pressures of mercury corresponding to different temperatures and indicates how completely mercury vapor may be eliminated by cooling the trap.

Temp.° C.	Vapor Pressure of Hg. in bars.[10]
−180 ° C.	2.3×10^{-24}
−78	4.3×10^{-6}
−40	0.0023
−20	0.029
−10	0.087
0	0.25
+10	0.65
+20	1.6
+30	3.7

For a very large number of experiments the presence of mercury vapor is not injurious. By use of solid CO_2 or liquid air the mercury vapor may be entirely eliminated.

As has been pointed out previously the vacuum actually attainable by the condensation pump is usually determined (according to Equation 19) by the rate at which gases are given off by the walls of the vessel being exhausted.

By means of a new type of vacuum gage devised by Dr. A. W. Hull of this laboratory, pressures as low as 10^{-5} bar, obtained by

[10] These vapor pressures are calculated from the formula

$$\log p = 11.27 - \frac{3243}{T}$$

which is obtained from data given by Knudsen (Ann. Physik. **29**, 179 (1909).

the condensation pump, have already been measured. There is little doubt but that pressures very much lower than this can be and have been obtained by cooling the bulb to be exhausted in liquid air so as to decrease the rate at which gases escape from the walls.

SUMMARY.

Two new types of condensation pump are described, one built wholly of glass and the other wholly of metal.

In these pumps a blast of mercury vapor carries the gas into a condenser. This action is similar to that in a steam ejector and in a Gaede diffusion pump. The method by which the gas is brought into the mercury vapor blast in the condensation pump is based on a new principle which is essentially different from that employed in the steam ejector or Gaede diffusion pump. In the new pumps the gas to be exhausted is caught by the blast of vapor and is forced by gas friction to travel along a cooled surface. By maintaining this surface at such a low temperature that the condensed mercury does not re-evaporate at an appreciable rate, it is possible to keep the mercury vapor from escaping into the vessel being exhausted. The action of this pump therefore depends primarily upon the fact that *all* the atoms of mercury striking a mercury-covered surface are condensed (no matter what the temperature), instead of even a fraction of them being reflected from the surface. It is for this reason that the term condensation pump is proposed.

The condensation pump is characterized by extreme speed (3000–4000 Cc. per second, or even more, if desired), by simplicity and reliability, and by the absence of lower limit (other than zero) to which the pressure may be reduced. By the aid of this pump pressures lower than 10^{-5} bars have been produced and measured.

To obtain the full benefit of the high speed of these pumps, it is necessary to use connecting tubing of very large size. Equations are given by which the effect on the speed of exhaustion produced by tubing of any given dimensions may be calculated.

The Future Prospects of Light Production. C. P. STEINMETZ. (*Proceedings of the Illuminating Engineering Society*, September 18–20, 1916. *American Gas Light Journal*, vol. cv, No. 13, September 25, 1916.)—Probably the most radical advance in illuminating engineering and light production that has been made through all the ages is embodied in the Welsbach lamp. It was the first time, outside of the temperature law, that energy had been conducted into radiation. We have a number of methods of light production which are not based directly on heat as an intermediate form. But still, modern lighting, especially electric lighting, is based on the temperature radiation; and in the field of temperature radiation or incandescent lighting, we probably consider the highest development of to-day, the highest efficiency of temperature radiators or illuminators represented by the acetylene flame and the gas-filled Mazda lamp. In the last fifteen years enormous advances have been made in increasing the efficiency of temperature radiation, and increasing the efficiency of the incandescent lamp from four watts per candle power up to that of the present lamp with less than half a watt per mean spherical candle power. It is not probable that the advance in temperature radiation in the near future will be nearly as radical. We appear to be approaching the limits of efficiency possible under the temperature radiation law, and it may be predicted that future advances will be measured in per cents rather than in the hundredths of per cents of the last fifteen years.

The temperature possible with hydro-carbon gases or vapor as a source of chemical energy necessarily is limited by the dissociation temperature of oxides of carbon and hydrogen in the acetylene flame. We are not far from those temperatures. In material, higher efficiency than given by the acetylene flame in light production under temperature radiation is not probable, except by using a radiator, using a combustible the oxide of which has a much higher dissociation temperature, such for instance as metallic magnesium. As a result of the present war, the commercial manufacture of magnesium has been developed to a considerable extent and it is quite likely that after the war when conditions have become normal, magnesium will be obtainable at prices comparable with those of aluminum. It is by no means impossible that if we realize such low prices of magnesium as appear possible under normal conditions, that magnesium as a combustible may become economically competitive as a light producer with the hydro-carbon flame. Perhaps after we have defined it broadly enough, chemical luminescence is not temperature radiation, because there is no temperature at which the radiation of the body would give a spectrum like that of the Welsbach mantle, because, at the temperature of the burning flame, these oxides, when heated electrically or protected from the flame gases do not luminesce.

ELECTROLYTIC DISSOCIATION IN NON-AQUEOUS SOLUTIONS.*

BY

HENRY JERMAIN MAUDE CREIGHTON.

Department of Chemistry, Swarthmore College,
Member of the Institute.

DURING recent years a great deal of work has been carried out in order to determine whether the laws which have been found to hold for electrolytes in aqueous solution also apply in the case of non-aqueous solutions. As a result of these investigations, in some cases it has been found the same laws which hold for aqueous solutions also apply to non-aqueous solutions; in many others this is apparently not true. Indeed, up to the present time, very few generalizations have been obtained. One of the most important generalizations that has been discovered is: a certain affinity between solute and solvent is necessary in order that conduction, that is, dissociation, may take place at all.[1]

Early Investigations.—One of the earliest and most systematic investigators in the field of non-aqueous solutions is Paul Walden, who, as early as 1899, found [2] that liquid sulphur dioxide has a remarkable power of dissolving the most varied substances, both inorganic and organic, the solutions often showing a characteristic color. Thus the iodides of sodium, potassium and ammonium dissolve in liquid sulphur dioxide forming yellow solutions. Among the organic compounds which are soluble in this solvent are alcohol, benzoic acid, phenol, ethyl acetate and aniline. The fact that the substances dissolved in this solvent readily react with one another indicates that they are dissociated. Thus, by double decomposition,

$$KI \times (CH_3)_4NCl = KCl \times (CH_3)_4NI.$$

All these substances are soluble in liquid sulphur dioxide, except potassium chloride which precipitates out of solution. The con-

* Communicated by Professor Creighton.

[1] Walker; J. Chem. Soc., **85**, 1082 (1904); Steele, McIntosh and Archibald; Proc. Roy. Soc., **74**, 325 (1905).

[2] Walden; Ber., **32**, 2862 (1899).

ductivity of sulphur dioxide solutions of many substances is large and, in some cases, greater than aqueous solutions of the same concentration. The increase of the molecular conductivity of these solutions with concentration is irregular, and in the case of the iodides much more marked than their aqueous solutions. The conductivity of ammonium, tetramethylammonium and tetraethylammonium iodides in liquid sulphur dioxide increases with the complexity of the cation. Since the difference between μ_{512} and μ_{16} for potassium iodide is greater in liquid sulphur dioxide than in water, it is probable that both the degree of dissociation and the electrolytic mobilities of the ions of the solute differ in the two solvents.

Later Walden [3] investigated the solvent property of a number of inorganic liquids, and determined the dissociation in the solutions by the conductivity method. Phosphorus trichloride and phosphorus tribromide were found to dissolve many organic compounds and the halides of arsenic, antimony and tin, but very few other inorganic compounds. Binary salts were found to dissociate to a considerable extent in phosphorus oxychloride. while ternary salts were observed to dissociate to but a slight extent. Arsenic trichloride was found to dissociate binary salts, but sulphuryl and thionyl chlorides had only a very slight dissociating power. Antimony trichloride yielded conducting solutions; the pentachloride did not.

Cady [4] observed that when a small quantity of a soluble salt (*e. g.*, sodium, potassium, silver, copper, barium, etc., salts) is added to liquid ammonia (spec. conductivity $= 71 \times 10^{-7}$) a solution of excellent conducting power is obtained. The presence of a small amount of water does not seem to have a measurable effect on the conductivity of either the ammonia or the substances dissolved therein. It is worthy of note that all the above mentioned dissociating solvents belong to the nitrogen or oxygen families.

Elaborate investigations in liquid cyanogen and hydrocyanic acid have been carried out by Centnerszwer, who found [5] that while the former has but a small dissociating power, the power of dissociation of the latter is even greater than that of water.

[3] Walden, Z. anorg. Chem., **25**, 209 (1900).
[4] Cady, J. Phys. Chem., **1**, 707 (1897).
[5] Centnerszwer, Z. physik. Chem., **39**, 217 (1902).

Thus, the equivalent conductivities of potassium iodide and trimethylsulphine iodide in liquid hydrocyanic acid, at 0°, are about four times as large as the corresponding values for aqueous solutions.

Dissociation of Complexes.—Solvents which do not dissociate ordinary electrolytes (salts, acids and bases) often cause certain complexes to dissociate to a large extent. For example, it has been shown [6] that although liquid bromine does not dissociate potassium bromide, tetramethylammonium iodide, trichloracetic acid, aluminum bromide, arsenic tribromide, or tin tetrabromide, concentrated solutions of the complexes $AlBr_7CS_2$ and $AlBr_5C_2H_5BrCS_2$ in this solvent exhibit a conductivity similar to that of typical salts in water. This behavior points to the fact that the complexes form addition compounds with the solvent, and that it is these that dissociate into ions.

Abnormal Electrolytes.—It has been found [7] that certain non-aqueous solvents, such as arsenic trichloride and sulphur dioxide, can dissolve and dissociate chlorine, bromine, iodine, sulphur, phosphorus, arsenic, antimony, and tin, substances which are neither acids, bases nor salts, and which do not possess any conductivity in aqueous solution. Thus in sulphur dioxide,

$$Br_2 = Br^+ + Br^-.$$

Substances which dissociate in this way are termed *abnormal electrolytes,* since the element itself must produce both anion and cation. Up to the present very little is known regarding abnormal electrolytes.

Influence of Concentration on Conductivity.—Just as in the case of aqueous solutions, the molecular conductivity of non-aqueous solutions usually increases with dilution. This behavior is illustrated by Table I, which contains some of the results of measurements made by Creighton [8] of the conductivity of acetophenone solutions of piperidine, camphorcarboxylic acid, bromcamphorcarboxylic acid and piperidine camphorcarboxylate, at 17°.

[6] Plotnikow, Ibid., **48**, 220 (1904).
[7] Walden, Z. physik. Chem., **43**, 385 (1903).
[8] Creighton, Ibid., **81**, 566 (1913).

TABLE I.

Dilution V	Molecular Conductivity $\mu \times 10^4$
PIPERIDINE	
2	10.74
4	18.16
8	30.08
CAMPHORCARBOXYLIC ACID	
2	58.2
4	79.2
8	100.0
16	107.5
32	111.7
BROMCAMPHORCARBOXYLIC ACID	
2.75	84.4
5.50	105.0
11.00	126.5
22.00	132.0
PIPERIDINE CAMPHORCARBOXYLATE	
2	344.8
4	350.4
8	406.4
16	492.8
32	585.6

In the case of non-aqueous solutions of a number of substances, the molecular conductivity has been found to decrease as the dilution increases. This decrease has been explained [9] on the assumption that the solute forms complexes with the solvent.

Conductivity of Salts.—It will be observed from the values for piperidine camphorcarboxylate, given in the preceding table, that, like in aqueous solution, the molecular conductivity of a salt of a weak acid and a weak base is considerably greater than that of either the acid or base alone. This behavior is more fully illustrated by Table II, which contains data obtained by Creighton [10] for acetophenone solutions of salts of camphorcarboxylic acid with a number of weak organic bases, at 17°.

[9] Steele, McIntosh and Archibald, Z. physik. Chem., **55**, 179, (1906); Sakhanov, J. Russ. Phys. Chem. Soc., **43**, 543.

[10] Creighton, Proc. and Trans. Nova Scotian Inst. Sci., **13**, 154 (1912).

TABLE II.

Base	Half-normal acetophenone solution. Mol. cond. of base. × 10^4	Mol. cond. of carboxylate × 10^4
Aniline	very small	72.2
Quinaldine	very small	139.6
Triisobutylamine	1.46	1128.2
Quinine	1.54	173.4
Quinidine	1.62	172.4
Nicotine	3.40	512.8
Conine	3.76	72.6
Tripropylamine	4.56	1439.4
Benzylamine	7.68	348.6
Piperidine	10.74	346.6

Although the conductivities of the carboxylates in Table II are twenty to several hundred times as great as those of the corresponding bases, the values are still very much smaller than in aqueous solutions of the same concentration.

Transport Numbers.—Many difficulties are encountered in making measurements of the transport numbers of the ions in non-aqueous solutions. Carrara [11] has been able to show, however, that in methyl alcohol the transport numbers of certain substances behave as if the solutions were more concentrated than corresponding aqueous solutions. Schlundt has found [12] that although the transport numbers of the ions of silver nitrate in various solvents are largely dependent upon the nature of the solvent, the values converge with increasing dilution. According to Franklin and Cady,[13] the velocities of a number of univalent ions in liquid ammonia (at −33°) are from 2.4 to 2.8 times as great as in aqueous solutions at 18°.

The Law of the Independent Migration of Ions.—Kohlrausch's law of the independent migration of ions has been found to apply to a number of non-aqueous solutions. As early as 1897, Carrara observed that the halogen ions have the same velocities in methyl alcohol as in water, and that the sodium and potassium ions have the same velocities when calculated from their different halogen salts. In other words, Kohlrausch's law applies to these solutions. The law has also been verified [14] for

[11] Carrara, Atti. accad. Lincei, **4**, 339 (1901).
[12] Schlundt, J. Phys. Chem. **6**, 159 (1902).
[13] Franklin and Cady, J. Amer. Chem. Soc., **26**, 499 (1904).
[14] Walden, Z. physik. Chem., **54**, 131 (1906).

solutions of a number of solutes in acetonitrile and epichlorhydrin. Dutoit and Gyr have shown [15] that the values for the equivalent conductivity of sulphur dioxide solutions of the bromides and iodides of potassium, rubidium, ammonium and tetraethylammonium conform with the law of the independent migration of ions. In their investigation of the conductivity of acetophenone solutions of a number of binary salts, Dutoit and Levier [16] have found that the molecular conductivity approaches a limiting value as in aqueous solutions. These limiting values have been found to satisfy the law of the independent migration of ions, but the ratios of the electrolytic mobilities of the ions of the salts have been found to differ from those in aqueous solutions. Although Kohlrausch's law applies to many non-aqueous solutions, solutions in a number of solvents have been investigated for which apparently this law does not hold even approximately.

Ostwald's Dilution Law.—Although the applicability of the dilution law to dilute aqueous solutions is substantiated by the results of a very large number of researches, the number of cases for which it holds in non-aqueous solutions is limited. It is possible that an extended study of this law with reference to non-aqueous solutions may lead to an explanation of the anomaly of strong electrolytes in aqueous solution. Wakeman [17] has found that the dilution law does not apply to strong electrolytes in mixtures of ethyl alcohol and water; and Walden and Centnerszwer [18] have observed that it is inapplicable to solutions of certain substances in liquid sulphur dioxide. On the other hand, Wildermann [19] has shown that this law holds for solutions of certain substances in absolute alcohol and in trichloracetic acid; and Godlewski [20] has obtained evidence that solutions of weak acids in ethyl alcohol and water obey the law. Dutoit and Gyr [21] have found that, above dilutions of 8000 liters, the dilution law is applicable to sulphur dioxide solutions of the iodides of certain alkali metals and to tetraethylammonium iodide.

[15] Dutoit and Gyr. J. Chim. phys., 7, 189 (1909).
[16] Dutoit and Levier, J. Chim. phys., 3, 435 (1905.
[17] Wakeman, Z. physik. Chem., 11, 49 (1893).
[18] Walden and Centnerszwer, Z. anorg. Chem., 30, 170 (1901).
[19] Wildermann, Z. physik. Chem., 14, 247 (1894).
[20] Godlewski, J. chim. phys., 3, 393 (1905).
[21] Dutoit and Gyr, J. chem. phys., 7, 189 (1909).

In an investigation on the conductivity of acids in absolute and aqueous alcohol, Goldschmidt [22] recently found that the behavior of the electrolytes is similar to their behavior in aqueous solution. The equivalent conductivities of the acids studied all approach limiting values as the dilution is increased. In Table III are given the equivalent conductivities at infinite dilution (Λ_∞) and the dissociation constants (k) for a number of acids in absolute alcohol, at 25°.

TABLE III.

Acid	Λ_∞	k
Picric	93	1.75×10^{-4}
Trichloracetic	88	1.5×10^{-6}
Trinitrobenzoic	86.5	7.0×10^{-7}
Dichloracetic	94	5.2×10^{-6}
Salicylic	86	2.2×10^{-4}

According to the recent investigations of Kraus and Bray [23] on the conductivity of dissociated substances in various solvents, all solutions of binary electrolytes obey the same dilution law. The mass action law (Ostwald's dilution law), however, is only obeyed at high dilutions; for higher concentrations the deviation from the mass action law is a function of the ionic concentration. For a given electrolyte, the trend of the conductivity curve for different solvents is determined by the dielectric constant of the solvent. The observed facts, both for dilute solutions and for solutions up to more than normal concentration, bear out the fundamental hypothesis of Arrhenius, according to which the dissociation of an electrolyte is measured by the conductivity ratio, $\frac{\Lambda}{\Lambda_\infty}$.

Chemical Activity.—Just as in the case of aqueous solutions, the chemical activity of substances in non-aqueous solution is associated with their conductivity, that is, with their dissociation. Thus, while investigating the catalytic decomposition of bromcamphorcarboxylic acid in acetophenone by various bases, Creighton [24] observed, for the majority of the bases employed, that the rate of decomposition of the acid increases with the conductivity of the base in this solvent. This behavior is illustrated by Table IV, in which are given the times required for 50 per

[22] Goldschmidt, Z. physik. Chem., **91**, 46 (1916).
[23] Kraus and Bray, J. Amer. Chem. Soc. **35**, 1315 (1913).
[24] Creighton, Z. physik. Chem., **81**, 543 (1913).

cent. decomposition of the acid by equivalent quantities of the different bases, and the specific conductivities of the bases.

TABLE IV.

Base	Time required for 50 per cent. decomposition of the acid	Specific conductivity of the base in 0.5 normal solution. $\kappa \times 10^7$
Piperidine	30 minutes	5.37
Isoamylamine	33 minutes	4.80
Benzylamine	32 minutes	3.84
Tripropylamine	34 minutes	2.28
Conine	40 minutes	1.88
Triisobutylamine	42 minutes	0.73
Quinine	52 minutes	0.77
Quinidine	53 minutes	0.81
Diisobutylamine	58 minutes	0.40
Quinaldine	80 minutes	much smaller
Aniline	about 24 hours	much smaller

The Dissociating Power of the Solvent.—The numerous investigations carried out during the past fifteen years in the field of non-aqueous solutions, show conclusively that the capacity for dissociation of those substances which are recognized in water as electrolytes, also occurs more or less distinctly in other solvents. Therefore, one of the most important problems in this field of research is the determination of the nature and origin of the dissociating power of solvents. With a view to throwing light on this problem, it has been sought to determine whether any relation exists between the other physical properties of a solvent and its dissociating power.

The Dissociating Power and Viscosity of the Solvent.—The numerous investigations of Jones and his co-workers during the past ten years have shown that a relation exists between the dissociating power of a solvent and its viscosity. As early as 1904 Jones pointed out [25] that the conductivities of comparable equivalent solutions of binary electrolytes in methyl alcohol, ethyl alcohol, other alcohols of the same series, acetone, etc., are inversely proportional to the coefficients of viscosity of the solvents. In order to determine more completely the relation between the conductivity of a solution and the viscosity of the solvent, Walden [26] has studied solutions of tetraethylammonium iodide in

[25] Jones, Amer. Chem. J., **32**, 409, 521 (1904).

[26] Walden, Z. physik. Chem., **55**, 207 (1906).

about thirty solvents. His results lead to the conclusion that, for a given temperature, the product of the viscosity (η) and the equivalent conductivity at infinite dilution (Λ_o) of different solutions is a constant quantity, *e. g.*,

$$\eta^{25°} \times \Lambda_o^{25°} = 0.7$$

Since he found further that the temperature coefficients of fluidity and conductivity are equal, it is evident that the above product is not only independent of the nature of the solvent, but independent of temperature as well.

The Dissociating Power and the Dielectric Constant of the Solvent.—By far the most important relation so far discovered between the dissociating power of a solvent and its other physical properties, is that which exists between the dissociating power of the solvent and its dielectric constant.

A connection between the dielectric constant of a solvent and its dissociating power was first suggested, when Thomson [27] put forward the hypothesis that "if the forces which hold the molecule together are electrical in their origin, . . . these forces will be very much diminished when the molecule . . . is surrounded by a substance possessing a very large inductive capacity." On the assumption that chemical forces are electrical in their origin, Nernst [28] later pointed out that solvents possessing the greatest dielectric constants should have the greatest dissociating powers. The combined statements of Nernst and Thomson are known as the Nernst-Thomson hypothesis.

In order to determine the relation between these two properties of the solvent, Walden has made [29] a systematic study of almost every type of organic liquid, including representatives of the alcohols, aldehydes, ketones, acids, acid anhydrides, chlorides, bromides, amides, esters, nitriles, thiocyanates and nitrocompounds. To facilitate the comparison of the dissociating power of the different solvents, one solute—tetraethylammonium iodide—was employed throughout. The values of the equivalent conductivity at infinite dilution were obtained by calculation and extrapolation, and the degree of dissociation of the solute was calculated in the usual way. In the great majority of the solvents

[27] Thomson, Phil. Mag. (v), **36**, 313 (1893).
[28] Nernst, Z. physik. Chem., **13**, 535 (1894).
[29] Walden, *Ibid.*, **46**, 103 (1903); **54**, 131 (1906).

studied, Walden found that the equivalent conductivity increased with dilution, as in aqueous solution; the irregular variation in the values for a few solvents has been ascribed to interaction between the solute and the solvent. Walden's results are in agreement with the Nernst-Thomson hypothesis, and show clearly the close parallelism between the dielectric constant (D) of the solvent and its dissociating power. The greater the dielectric constant, the greater is the percentage dissociation of the solute for a given dilution. This relation is shown by the data contained in Table V.

TABLE V.

Solvent	D	Λ_∞ at 25°	Percentage Dissociation		
			v = 100	v = 1000	v = 2000
Water	81.7	112	91	98	99
Formamide	84.0	25	93	98	98
Glycollonitrile	67.9	71.5	93	98	99
Succinonitrile	57.3–61.2	35.5 (60°)	90	95	96
Citraconic anhydride	39.5	22.5	82	93	94
Nitromethane	38.2–40.4	120	78	92	93
Furfuraldehyde	36.5–39.4	50	ca 78	91	93
Lactonitrile	37.7	40	..	89	91
Acetonitrile	35.8–36.4	200	74	90	92
Methylthiocyanate	33.3–35.9	96	77	89	91
Ethylene glycol	34.5	8	78	89	..
Nitrobenzol	33.4–37.4	40	71	88	90
Methyl alcohol	32.5–37.4	124	73	88	90
Methylcyanacetate	28.8	29.5	69	84	87
Propionitrile	26.7–27.2	165	65	84	87
Ethylthiocyanate	26.5–31.2	84.5	63	83	86
Ethylcyanacetate	26.2–26.7	28.2	65	83	87
Benzonitrile	26.0	56.5	61	80	84
Epichlorhydrin	26.0	66.8	60	81	85
Acetylacetone	25.1–26.0	79	..	83	87
Ethyl alcohol	21.7–27.4	60	54	78	82
Acetone	20.7–21.9	225	50	74	80
Ethyl thiocarbamide	19.4–22.0	106	..	66	..
Acetic anhydride	17.9	76	58	79	84
Benzaldehyde	14.5–16.9	42.5	51	73	78
Phenylacetonitrile	15.0–16.7	36	46	74	79
Acetylbromide	16.2	114	47	73	78
Acetylchloride	15.5	ca 172	46	72	79
Salicylaldehyde	13.9	25	34	55	61

An interesting empirical relation yielded by Walden's data is expressed by the formula:

$$D\sqrt[3]{v} = \text{constant},$$

where D is the dielectric constant of the solvent and v is the dilution at which the degree of dissociation of tetraethylammonium iodide has a given value in a particular solvent. The high dissociating power of water agrees with its position in the table, for of all the common solvents it possesses by far the greatest dielectric constant. Formamide, which has a dielectric constant slightly greater than that of water, imitates in a remarkable manner many of the physical characteristics and constants of water. The dissociation of binary electrolytes in this solvent is even greater than in water. In this connection the high dielectric constant (95.0) of liquid hydrocyanic acid and its high dissociating power (page 4) is of interest.

Brühl[30] has pointed out that no absolute proportionality exists between the dissociating power of a solvent and its dielectric constant, nor can be expected to exist, inasmuch as the dielectric constant varies greatly with temperature and also with the frequency of the electric waves. He regards the dissociating power of a solvent to be due to a form of energy which he calls the "medial energy;" this, although not identical, is connected with the heat energy of the solvent. Since physical and chemical changes are only associated with changes in energy, the internal energy of a solvent cannot be actually measured; but it is probable that the internal energy is greatest in those solvents with the highest specific heat, and heat of evaporation or fusion. Examination of these physical constants for a large number of liquids has indicated that high values are always associated with high dielectric constants and high dissociating powers.

The Dielectric Constant and the Associating Power of the Solvent.—According to Walden,[31] the value of the dielectric constant of a liquid depends largely upon the presence of certain chemical groups. He has found that the dielectric constant is increased by the substitution of the following groups, the magni-

[30] Brühl, Z. physik. Chem., **30**, 1 (1899).
[31] Walden, *Ibid.*, **70**, 569 (1910).

tude of the increase increasing in the order from left to right: I, Br, Cl, F, NH_2, CN, CO_2H, CHO, CO, NO_2, OH. This is almost the same order in which Auwers found[32] that the substitution of these groups increased the ability of the solvent to prevent the association of the molecules of the solute. The influence of these groups upon the dielectric constant and upon the associating power of a solvent indicates that there must be some connection between these two properties. It is evident that with increasing power of dissociation there must occur not only an increase in the dissociation of the molecules into ions but also an increase in the dissociation of the polymerized molecules into simple ones.

A comparison of the values of the abnormality factor, *i*. (*i. e.*, the number of times the osmotic pressure, the freezing-point lowering, etc., of solutions is greater than the normal value), which have been obtained for non-aqueous solutions by conductivity, cryoscopic and ebullioscopic methods, often leads to contradictory results. Sometimes *i* values which are less than unity are obtained by the latter methods, even though the presence of conductivity indicates that the solute must be dissociated to a considerable extent in the solution. This anomaly may be explained, however, if we assume that in such cases the number of molecules of solute which dissociates is exceeded by the number which associates. It has been found[33] when the *i* values for tetraethylammonium iodide obtained by ebulliscopic measurements are compared with those obtained by conductivity measurements, that although they are of the same order there is by no means complete agreement. With the alcohols as solvents, the values of *i* obtained by the osmotic method are always smaller than those obtained by the conductivity method, the divergence between the two sets of values increasing with the concentration of the solute. Sometimes the same solvent possesses the power of dissociating certain solutes and associating others. For example, while formic acid dissociates potassium chloride and tetraethylammonium iodide, hydrochloric acid apparently associates to double molecules in this solvent.[34]

---

[32] Auwers, *Ibid.*, **42**, 513 (1903).

[33] Walden, Z. physik. Chem., **55**, 281 (1906).

[34] Zanninovich-Tessarin, Z. physik. Chem., **19**, 257 (1896).

The Dissociating Power and the Degree of Dissociation of the Solvent.—The work of Ramsay, Guye, Beckmann, and others has shown that, in general, the alcohols, phenols, aliphatic acids, aldehydes, ketones, nitriles, amides, urethanes and thiocarbimides are more or less associated in the liquid state. Further, it has been found that these liquids are usually good solvents, and that they possess dissociating power. It has been observed [35] that solutions of salts and organic acids in associated liquids possess high conductivities. Dutoit and Friderich have found [36] that the behavior of binary salts in solutions of acetone and acetonitrile is analogous to that exhibited in aqueous solution. The conductivity of these solutions increased in accordance with the dilution law, and the temperature coefficients of conductivity were normal. In the case of ternary electrolytes, however, the conductivity was found to be much lower, not exceeding one-fourth of the value obtained for binary electrolytes. In view of their own results and those of other investigators, Dutoit and Friderich conclude that when the same electrolyte is dissolved in different solvents, the values obtained for the equivalent conductivity at infinite dilution are direct functions of the degree of association of the solvent, and inverse functions of its viscosity. In contradiction to this conclusion, the results of Euler [37] show that solutions of potassium iodide in nitrobenzol, benzonitrile and furfurane exhibit considerable conductivity, and, therefore, are dissociated, even though these solvents are unassociated.

A close parallelism exists between the degree of association of a solvent and its dissociating power; and solvents which are largely associated invariably have high dielectric constants. The reverse is not true, however, for many liquids with high dielectric constants are not associated. The relation between the degree of association of a solvent and its dielectric constant is shown by the data contained in Table VI.[38]

---

[35] Dutoit and Aston, Compt. rend., **125**, 240 (1897),

[36] Dutoit and Friderich, Bull. Soc. Chim. (iii), **19**, 321 (1898).

[37] Euler, Z. physik. Chem., **28**, 619 (1899).

[38] Walden, *Ibid.*, **54**, 129 (1906).

TABLE VI.

Substance	Association factor.	Dielectric constant.
Formamide	6.18	84
Water	3.81	81.7
Formic acid	3.61	58
Acetic acid	3.62	6.3
Methyl alcohol	3.43	32.5
Glycol	2.92	34.5
Ethyl alcohol	2.74	21.7–27.4
Acetonitrile	1.67	36
Propionitrile	1.45	26.8
Acetone	1.26	21.3
Benzonitrile	0.97	26.0
Nitrobenzol	0.93	35

Liquid ammonia, which has a high dissociating power (page 3), is probably highly associated and has a high dielectric constant.[39] The influence of the degree of association of the solvent upon its dissociating power is clearly seen in the case of solutions of silver nitrate in benzonitrile and propionitrile. According to Schlundt,[40] the dissociation of this solute is markedly greater in the latter than in the former solvent. Although the dielectric constants of these solvents are almost equal, it will be observed from the values given in Table VI, that while the molecules of benzonitrile do not associate, those of propionitrile polymerize to a considerable extent. Sakhanov [41] has found that the Nernst-Thomson hypothesis only holds when the dielectric constant is not too small. When this constant is small, the dissociating power of the solvent depends solely upon its constitution and is entirely independent of the magnitude of the dielectric constant.

The Influence of Unsaturated Valences on the Dissociating Power of the Solvent.—It has been suggested that only those solvents which contain polyvalent elements with unsaturated valences possess dissociating power. Thus, the dissociating power of water and the lower alcohols is attributed to the presence of bivalent oxygen which tends to become tetravalent; that of hydrocyanic acid, hydrazine, the nitriles, etc., to the presence of trivalent nitrogen which tends to assume the pentavalent condition. However, this theory fails to explain why benzol, cyan-

[39] Brühl, Z. physik. Chem., **27**, 319 (1898).
[40] Schlundt, J. Phys. Chem., **5**, 168 (1901).
[41] Sakhanov, J. Russ. Phys. Chem. Soc., **42**, 1363.

ogen, carbon disulphide and phosphorus trichloride, all of which contain polyvalent elements with unsaturated valences, apparently have no dissociating power.

Union of Solute With Solvent.—Considerable evidence has been obtained during the past few years which points to the participation of the solvent in the process of dissociation, through a union with the solute. Recent investigation indicates that a complete knowledge of this phenomenon will probably throw a great deal of light on the nature of the dissociating power of solvents.

Theories.—It has been suggested that the process of dissociation begins when the solvent unites with the positive and negative particles of the molecules of the solute, and that as soon as all the latent atom valences are saturated, these particles are free to assume the ionic state. The electrostatic attraction between the oppositely charged particles, which tends to hold them together in the molecule, is so much smaller the greater the dielectric constant of the solvent. Thus, it is possible for oppositely charged particles or ions to exist at shorter distances apart in a solvent with a high dielectric constant than in one with a small dielectric constant. Consequently, a smaller volume of the first solvent than of the second would be required to obtain the same degree of dissociation of a solute. It is probable that it is the chief function of chemical affinity to produce the ions, and it is the function of the dielectric property of the solvent to hold the ion and its integument of solvent together, once the ion is formed. While decrease in electrostatic attraction alone would be insufficient to explain dissociation and, still less, the freedom of the ions, on the other hand, dissociation as an influence of chemical affinity is in agreement with many observed facts.

It is impossible within the scope of this paper to give all the different hypotheses that have been put forward to account for the dissociating power of solvents. In the case of each, many difficulties and contradictions are encountered. All these hypotheses fail when we pass from the general to the particular. One of the greatest difficulties at present is to explain the simultaneous occurrence of both dissociating and associating powers in the same solvent. Although it is probable that all the hypotheses put forward contain some truth, the whole truth will doubtless be forthcoming only when our knowledge regarding the unions

which occur between solvent and solute becomes more extensive. Much experimental data have still to be accumulated systematically before a general theory of the dissociating power of solvents can be established.

It is probable that the dissociating power of a solvent cannot be regarded as a well defined physical constant, but that it must be considered as a specific property of the solvent, which has its origin in the physical constants existing between solvent and solute.

Steel Conductors for House Wiring. ANON. (*Electrical Review*, vol. 69, No. 9, August 26, 1916.)—In order that the central stations of the country may widen their fields of service, there has been an insistent demand for some time for a cheaper system of electric wiring which would be applicable especially to already built houses, cottages, and flats of the most modest type. The concentric system, which has been widely applied in certain countries of Europe, has been looked to by many as a system which would meet this demand. To the disappointment of many, trial installations in this country have not indicated economies over the usual methods of wiring.

There is another method of reducing the cost of small wiring installations which has received little or no consideration in this country. Installations in small residences invariably use more copper in the conductors than is necessary from the electrical standpoint, and the high price of copper at the present time makes this item more important than it formerly was. The smallest size of wire that is permitted for either main or branch circuits is No. 14 B. & S. gauge, which has a rated capacity of 15 to 20 ampères, according to the kind of insulation with which it is provided. Wire as large as this is required for mechanical reasons, since a smaller size would be more likely to become broken and lead to trouble and possibly hazards. The carrying capacity of No. 14 wire is much more than sufficient for most branch circuits, since such circuits are limited to a connected load of 660 watts, which upon a 110-volt circuit is equivalent to six ampères. Copper is chosen as the material for conducting wires on account of its high conductivity. It is evident here that the conductivity is much higher than necessary from electrical considerations, and a cheaper material could be substituted without detriment. Such material can be made available in the form of insulated iron or soft-steel wire. Such wire would have about seven times the resistance of a copper wire of the same cross-section, and in small sizes the magnetic permeability would be of no consequence in alternating-current circuits of commercial frequencies, so far as reactance and skin effect are concerned.

SLAB DEFLECTION AND SUBSIDENCE OF COLUMN SUPPORTS IN A FLOOR TEST OF INTERNATIONAL HALL, CHICAGO, MADE SEPTEMBER, 1913.*

BY

HENRY T. EDDY, C.E., Ph.D., LL.D.,
University of Minnesota.

REINFORCED concrete floor slabs are somewhat imperfectly elastic, and in testing them an allowance is commonly made for this fact by the requirement that in case of any excessive deflection at least 80 per cent. of it shall disappear within a week after the removal of the load which produced the deflection. This requirement recognizes the imperfection of the elastic properties of the slab in two ways, since first, it does not forbid some residual permanent deflection, and, further, it does not require immediate recovery, neither of which concessions could be made in case of a perfectly elastic structure.

Few materials of construction are so perfectly elastic as actually to make an immediate and complete recovery, but a much larger margin is allowed to reinforced concrete than to most other materials. It should be noticed that on account of its being a composite structure, composed partly of steel and partly of concrete, of which the steel is more nearly perfectly elastic than the concrete, a floor slab with steel massed in the column heads will have a more prompt and complete recovery than one with so-called drop heads of concrete in place of the heavy reinforcement in the column heads.

But in the retardation or time lag of slab recovery a phenomenon is exhibited which is not found to any perceptible extent in other kinds of materials of construction in ordinary use. Since recovery from slab deflection is gradual and may never be complete, and since a corresponding gradual increase of deflection must occur under a load, it has been argued by some that final stability under a load is impossible. The permanence, however, of ancient concrete structures seems to show that there must be a limit to the deformations and deflections that will take place

* Communicated by the Author.

under loads, just as there is to the recovery after removal, and it must be admitted that concrete is not really plastic, although the property of concrete to which attention has just been directed bears some of the marks of plasticity. Were concrete really plastic under ordinary stresses, that fact would spell the ultimate destruction of buildings and bridges made of that material. But concrete is a kind of artificial rock and evidently reaches, in time, a permanent and invariable state in which progressive changes no longer take place, although, in course of hardening, phenomena may occur which, if not ultimately checked, would involve final collapse.

Now the theory of the flexure of slabs differs from that of continuous beams in important particulars, one of which is that the applied moments and the observed resisting moments are not equal to each other, a fact the reasons for which are discussed elsewhere. But to this fact it is due that the economical and safe depth or thickness of slabs for any given span is small compared with that of beams, a fact which partially obviates one of the great drawbacks that exists to the use of continuous beams, viz., the large stresses introduced by any accidental subsidence of supports.

As just stated, one of the most serious practical objections to the employment of continuous beams lies in the very large stresses induced by settlement of supports, because this will usually entirely disarrange the stresses for which the structure was designed. This hazard has operated very largely to prevent the construction of continuous bridges consisting of several successive spans. But a subsidence of a magnitude which might produce dangerous stresses in a structural steel building may be taken up in course of construction in a reinforced concrete building without requiring special attention, since the relatively large flexibility of these slabs is such as to make the effects of moderate subsidences inconsiderable compared with the effects of subsidences of the same absolute amount in bridges and deep girders.

The structural utility of continuous panels is so great as to outweigh their risks and practically to necessitate their adoption. The fact previously stated that the applied moments and resisting moments in slabs are unequal does not, however, prevent us from applying the theory of flexure to slabs as well as to beams, al-

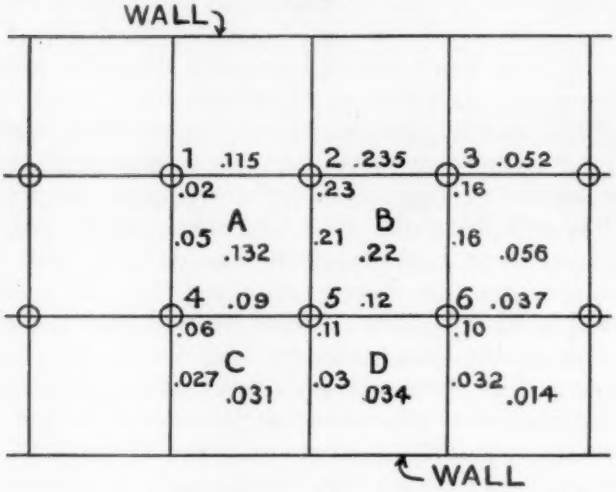
though it does prevent us from calculating the moment of inertia of the resisting materials in slabs in the same manner as in beams. But those deductions from the theory of flexure which are independent of the magnitude of the moment inertia are valid equally for beams and for slabs. Such, for example, are the relative deflections and vertical displacements of different points in the span. This it is which has made it possible to treat with success an important question which arose in the discussion of the test of the floor of International Hall.

In this floor slab the foundations of the columns proved insufficient to carry the test loads without yielding by amounts large enough to have considerable effects upon the stresses and deflections of the four loaded panels, each of which was 18 by 18 feet square. The floor as tested was a deck slab with no columns on its upper side. It was three panels wide and nine panels long, and was built into the surrounding walls of an old brick building by cutting into them somewhat for space to place steel and pour concrete, so that the edges of the slab were made integral so far as possible with the walls. The four panels which were tested formed a square near the middle of one side of the slab, two of them being in one tier of wall panels and the other two in the middle tier adjacent to them. In this floor, with its two rows of supporting columns parallel to the long sides of the building, certain vertical displacements were measured at the columns and at mid-span between columns and walls, both before and a week after the removal of the final test load, and the question was to determine whether the recovery was as much as 80 per cent. of the maximum deflection, and so whether there still remained as much as 20 per cent. of the maximum. The solution of this problem implicitly requires the determination of the magnitude of the vertical displacements which would occur in the slab by reason of the subsidences of the column supports only; for the actual vertical displacement at any point of the slab is the sum of two kinds of displacement; first, that due to the bending by reason of subsidence of the points of support, and, second, that due to bending by reason of the applied load. The fact that the subsidence of columns was itself also due to the applied load is immaterial, since the effect would be the same were the subsidence due to some other cause.

When that part of the vertical displacement at any point which is due to the subsidence of supports is subtracted from the actual vertical displacement observed at that point, the remainder is the true deflection and may be either that due to the effect of the load in bending the slab or to the residual bending effect after removing the load, according as the load is still resting upon the slab or has been removed. The ratio of the remainder after removal to the remainder before removal will show how much the recovery falls short of being complete.

Let these four panels be designated by *A*, *B*, *C*, *D*, respec-

FIG. 1.



tively, as shown in Fig. 1, with columns numbered from 1 to 6. Panel *B* is the centre of the entire floor. Let the reinforced direct belts extending across the slab over the columns be regarded as continuous beams fixed horizontally at the walls. The assumption that they are fixed at the walls is probably not entirely correct, but more nearly so than the assumption of mere support at the walls. It is found that the latter assumption gives results which do not differ much from those obtained by assuming the ends to be fixed in direction as well as position. If L be taken as the distance between successive columns, these belts or beam strips, which may be taken roughly as having a width of $0.5\ L$, are not of uniform moment of inertia throughout their lengths,

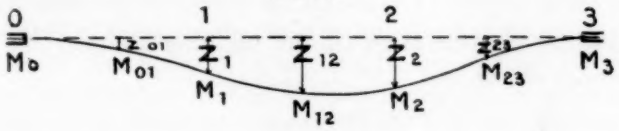
but will, for the purpose of preliminary investigation, be assumed as uniform, and their irregularity of cross-section will be allowed for later.

Given a uniform continuous beam of three equal spans, each of length L, as shown in Fig. 2, whose extremities are fixed horizontally on the same level, but whose intermediate points of support at points 1 and 2 are depressed by the observed subsidence z_1 and z_2, respectively, below the level of the extremities, to find the displacements z_{12}, z_{01}, z_{23}, at the middle of the centre and end spans respectively, there being no stresses or displacements due to any other cause than the subsidences z_1 and z_2.

Let M_0 and M_3 be the moments at the extremities and M_1 and M_2 at the intermediate supports, respectively.

Then, by making use of the theorem of three moments, which applies in its general form to any two successive spans of a straight beam with supports at any arbitrary levels, we have the

FIG. 2.



following four equations by taking four successive pairs of spans, as follows: The first pair, Equation (1), consists of a span of zero length and a span extending from the wall at 0 to the first row of columns at 1. The effect of a span of zero length is to give the slab a fixed horizontal direction at the wall. The second pair of spans, Equation (2), extends from the wall at 0 to the first row of columns and from the first to the second row of columns at 2. The third pair, Equation (3), extends from the first row of columns at 1, across the second row to the other wall at 3, and the fourth pair, Equation (4), from the second row of columns at 2, to the second wall at 3, and includes a span of zero length at that wall.

The notation may be understood from Fig. 2, in which the tangents at the 0 and 3 are fixed in a horizontal position and the vertical displacements or subsidences at the intermediate supports 1 and 2 are of known amounts, z_1 and z_2, and the vertical displacements at mid-span are designated by z_{01}, z_{12}, and z_{23},

respectively, while the applied bending moments are denoted by the letter M with corresponding subscripts, and the length of the equal spans between supports by L.

$$6\,EIz_1=(2M_0+M_1)L^2 \quad (1)$$
$$-6\,EI(2z_1-z_2)=(M_0+4M_1+M_2)L^2 \quad (2)$$
$$6\,EI(z_1-2z_2)=(M_1+4M_2+M_3)L^2 \quad (3)$$
$$6\,EIz_2=(M_2+2M_3)L^2 \quad (4)$$

Considering now the mid-displacement z_{12} of the middle span 12, it may be expressed in terms of the two end moments and end displacements of that span as follows:

$$6\,EI(z_1+z_2-2z_{12})=\tfrac{3}{4}(M_1+M_2)L^2 \quad (5)$$

as appears from the fundamental equation of moments and shears used in establishing the equation of three moments.

The solution of these five simultaneous linear equations by the method of indeterminate multipliers or otherwise gives as a result

$$z_{12}=5/8(z_1+z_2) \quad (6)$$

A similar consideration of the mid-displacement z_{23} of the end span 23 shows that

$$6\,EIz_{23}=1/8(M_2+5M_3)L^2 \quad (7)$$

The solution of the first four simultaneous linear equations and (7) gives

$$z_{23}=(19z_2-4z_1)/40 \quad (8)$$

and by symmetry

$$z_{01}=(19z_1-4z_2)/40 \quad (9)$$

Hence

$$z_{01}+z_{12}+z_{23}=z_1+z_2 \quad (10)$$

which is a fundamental equation of displacements in this case of no loads.

In case the assumption were that the walls are simple supports and exert no restraint, the values of the displacements at mid-span have been found to be

$$\left.\begin{aligned} z_{12}&=23(z_1+z_2)/40\\ z_{23}&=(29z_2-6z_1)/40\\ z_{01}&=(29z_1-6z_2)/40 \end{aligned}\right\} \quad (11)$$

from which it appears that this would make the displacement at mid-span of the middle span a little less and at mid-span of the

end spans a little greater than when the ends are fixed, and the same kind of effect, but of smaller amount, will be produced by any relaxation of fixity at the walls.

It will be noticed from (11) that

$$z_{12} = z_{01} + z_{23}$$

It is evident that the floor under consideration may be taken to consist of beam strips not only crosswise from side wall to side wall, as has just been done, but also as made up of beam strips parallel to the side walls and extending lengthwise of the building, and that the agreement of the results of computations by these two methods will tend to establish their correctness. Suppose the beam strips to each have a width of $\frac{1}{2}L$ extending over the two rows of columns parallel to the long side walls, with a strip of the same width lying between these two. If the length of these strips be taken as $4L$, they may be assumed to have their ends practically fixed horizontally, with certain observed vertical displacements at the three intervening columns. The problem in this case is this: Given the vertical displacements z_1, z_2, and z_3 at points of support 1, 2, and 3 of a beam fixed horizontally at the ends 0 and 4, to find the vertical displacements z_{01}, z_{12}, z_{23}, and z_{34}, at mid-span between each pair of supports. The equations are like those already used in the case of three spans, and the values arrived at in the same manner are:

$$\left.\begin{aligned} z_{01} &= (106z_1 - 21z_2 + 6z_3)/224 \\ z_{12} &= (142z_1 + 133z_2 - 30z_3)/224 \\ z_{23} &= (142z_3 + 133z_2 - 30z_1)/224 \\ z_{34} &= (106z_3 - 21z_2 + 6z_1)/224 \end{aligned}\right\} \quad \ldots\ldots (12)$$

It will be noticed that in this case

$$z_{01} + z_{12} + z_{23} + z_{34} = z_1 + z_2 + z_3 \quad \ldots\ldots (13)$$

which is an equation of deflections for four spans similar to (10) for three spans.

On Fig. 1, which shows a plan of the panels of the test, are inscribed, at columns 1 to 6, the amounts of the vertical displacements observed under the final load in inches, and at mid-span between these columns the vertical displacements, computed according to the foregoing equations, that would take place in a uniform slab by reason of the displacements at the columns without applying any load to the slab except the reactions at the

columns which are necessary to produce the displacements at the columns.

Displacements at panel centres are also given. These last are computed both by taking beam strips crosswise and lengthwise of the floor midway between the beam strips already computed across the tops of the columns. Practically the same values at panel centres are obtained from the computation by strips crosswise as lengthwise. This affords a satisfactory check on the work. Were the slab of uniform moment of inertia throughout, the displacements which have been computed at mid-spans and panel centres would express the position of the surface from which true deflections should be measured, or the surface of zero deflection from which deflections due to the load or lack of recovery are to be measured. That however, is not entirely correct for a floor slab, by reason of the great relative stiffness and extent of the column heads, which must be allowed for. The side belts are weaker near mid-span than elsewhere. The kind of effect that this produces may be made evident by considering what would be the effect of joints at mid-span of the beam strips across the floor. That would cause angles in the strips at each mid-span with comparatively straight portions over the columns. At mid-span in the centre of the strip the displacement would evidently be increased by such joints or by any weakness of this kind. In the case of the test under consideration it is estimated that the combination of a central conduit in each panel tier parallel to the long side walls, with the lack of columns integral with the slab above it, added not less than 25 per cent. to the computed vertical displacements at the centres of panels *A* and *B* and midway between those points, these being the points of maximum deflection at which the percentage of recovery is to be determined.

The accompanying table gives in column 1 the computed vertical displacements at these points, and in column 2 these amounts increased by 25 per cent., to take account of the increased displacement by reason of lack of uniformity in the slab. Column 3 gives the observed displacements under maximum load, and column 4 the observed displacement after removal of the load and recovery. Column 5 is the difference between column 3 and column 2, or the deflection under the load. Column 6 is the difference between column 4 and column 2, or the deflection

after removal of load and recovery. Column 7 is the ratio of column 6 to column 5, or the percentage which which the residual deflection is of the maximum. Column 8 is 100 per cent. less the per cent. in column 7, or the percentage of recovery, which has a mean value of 80.7.

TABLE OF VERTICAL DISPLACEMENTS AND DEFLECTIONS IN INCHES.

	1	2	3	4	5	6	7	8
At centre of	Computed for uniform slab	Increased 25 per cent. not uniform	Maximum observed displacement	Minimum observed displacement	Maximum deflection column 3 less column 2	Minimum deflection column 4 less column 2	Percentage of residual deflection	Percentage of recovery
Panel *A*..	0.13	0.16	1.04	0.38	0.88	0.22	25	75
Span 2–5..	.21	.25	.95	.37	.70	.12	17	85
Panel *B*...	.22	.264	.98	.38	.716	.116	16	84
Mean...	0.19	0.225	0.99	0.38	0.765	0.152	19.3	80.7

The application of a rule requiring a recovery of 80 per cent. in this case, however, discriminates against the floor structure and attempts to have it make good the shortcomings of the faulty foundations on which the columns rest. At the time of the maximum load, when subsidence of the columns took place, the columns were subjected to a very considerable bending moment by reason of the tipping of the floor, which was integral with the column heads. This caused the foundation of each column not only to sink vertically, but to tilt at the same time in an inelastic displacement. On removal of the load, any restoration of the foundation either to its original vertical position or level would have to be accomplished, not by any elastic effort of the foundation itself, but by an elastic effort coming from the floor itself. Not only was work required to displace the foundation at first, but additional work will be required after the removal of the load to right the foundation, or else the foundation will itself tend to restrain the slab and hold it in its displaced position not merely by reason of its vertical displacement, but by reason of its tilted position in addition to that. Thus it is that the displaced foundations tend to prevent the recovery of the slab in other ways than merely by the vertical displacements which have been considered in the preceding computations.

Rocks Made to Tell Their Own Story. ANON. (*United States Geological Survey Press Bulletin*, No. 286, September, 1916.)—The walls of the Grand Canyon in Arizona form a great natural geologic section, in which each layer of rock is in its original position relative to those above and below it. In few other places, however, is the story of the upbuilding of the earth's crust so plainly and impressively told. As a rule, the geologist who would decipher the records of the rocks must get a bit here and a bit there. He may find the edges of some beds exposed in a river bluff and others sticking out on a steep mountain side. He determines by fossils or other means the order in which the beds were deposited, and by putting all his information together he constructs what he calls a columnar section for the district in which he is working—that is, a section showing the order, thickness, and character of the beds. Such a section discloses the strata that form the upper part of the earth's crust at that place, just as a slice of layer cake shows at a glance the various layers of which it is composed.

After a number of districts in a region have been studied and their general columnar sections determined, the geologic history of the region can be learned by comparing these sections, just as the engineer who is drilling for low-grade copper ores compares his drill records and thus learns the outlines of the ore body. Such a comparison of the beds at one place and another shows how certain beds change in character and thickness from place to place or even thin out and disappear. It enables the geologist to draw some conclusions as to the former distribution of land and sea, to distinguish the deposits laid down in deep water from those spread by rivers over their flood plains, and to reconstruct in imagination the course of events at a time long before the beginning of the Grand Canyon. Such a comparison has recently been made for Arizona and is published by the United States Geological Survey, Department of the Interior, as Professional Paper 98-K, by F. L. Ransome, geologist. The report is obtainable on request from the Director.

Semi-steel. D. MCLAIN. (*Proceedings of the American Foundrymen's Association*, September 11–15, 1916.)—Semi-steel, although not recognized in iron and steel nomenclature, ranks among the most valuable products of the gray iron foundry. More than 100,000 pounds were produced last year to meet the demand for stronger metal and lighter sections. Semi-steel is made in the same cupola with regular gray iron mixtures. No extra coke, special appliances, fluxes or new equipment are necessary. It is made in the same heat with other mixtures. It may be melted in the early part of a heat, in the middle, or in the last part of a regular heat. It may begin with 30 to 40 per cent. steel on the bed and then follow with 20 to 25 per cent. steel. The product is 25 to 60 per cent. stronger than gray iron, thus permitting a large reduction in weight.

STRESSES IN IMPACT.*

BY

ARMIN ELMENDORF,

Instructor in Mechanics, University of Wisconsin, Madison, Wis.
Member of the Institute.

THE physical laws of most value in the study of the phenomenon of impact are the laws of conservation of momentum and conservation of energy. By means of the principles expressed by these laws the velocities of two colliding bodies after impact may be determined for all conditions, such as elastic, semi-elastic, and "dead" impact; and the energy lost may be computed when the physical properties of the material are known. Stresses due to suddenly applied loads may also be obtained, with the aid of certain assumptions, when the elastic limit of the material has not been exceeded. In case the elastic limit of the material has been exceeded theory casts little light upon the actual stresses or even approximate stresses such as the modulus of rupture or the stress at failure, which is of so much importance in engineering construction. How do the stresses at failure of a wooden beam, for example, compare with the corresponding stresses for a beam loaded statically to rupture? Will a material absorb more or less work to the point of failure when suddenly loaded than it does for slow loading? Is the modulus of elasticity the same for the two methods of loading? Will a beam deflect farther at rupture in impact than it does in static bending? While the latter question may be readily answered by making a few simple tests, the matter of stresses is not so readily put aside and requires for its solution both the application of the laws of impact and experimental data of a somewhat unique nature. It was primarily the determination of the stresses actually set up in impact that prompted the investigations presented herewith.

Before proceeding to the tests themselves it will be necessary to analyze the phenomena of impact and to formulate the theory involved. In the study of the theory the conditions under which the tests were made will be kept in mind constantly and no assumptions will be made that cannot be amply justified by the results of the test.

* Communicated by the author.

For the purpose of this study we will imagine the usual wooden beam supported at the ends and struck at the centre by a falling weight or tup whose mass is at least ten times that of the beam. The beam is rectangular in section, and the nose or surface of contact of the tup is rounded so that undue crushing of the fibres on top of the beam will be avoided. The tup is allowed to fall from a height sufficiently great to break the beam with a single blow. At the instant of contact the pressure between the tup and the beam is zero. Then, as the tup proceeds in its descent, dropping through a distance ΔS, there results, first, a slight depression or indentation in the beam due to the inertia of the particles of the beam in the path of the motion; second, a displacement of the centre of gravity of the section of the beam under the tup equal to ΔY, so that the difference ΔS-ΔY represents the depth of the indentation; and, third, a wave is sent out to each side with a speed equal to that of the velocity of stress propagations in timber. Inasmuch as ΔY is small, the upward pressure of the beam due to flexure is as yet quite negligible, and the actual pressure between the beam and the tup may be considered as due entirely to the inertia of the particles in the vicinity of the centre. As the descent proceeds with ΔS still very small, the difference ΔS-ΔY becomes constant, and soon the centre of gravity of the section under the tup has the same velocity as the tup itself. This does not imply, however, that the sections to either side of the centre have attained velocities proportional to their proximity to the centre or to the deflections associated with a deflection ΔY at the centre, due to static loading. The latter state is merely the limiting or equilibrium condition that the beam assumes as the deflection proceeds. Since the velocity of stress propagation for timber is about 13,000 feet per second, and the total time for the deflection has a minimum value of 0.02 second for the tests made on 50-inch beams, it may be assumed that this condition of equilibrium has been reached a relatively long time before the maximum deflection has been attained. When this condition has been arrived at the beam has an elastic curve very nearly the same as the elastic curve in static bending, and the pressure between the beam and the tup is due solely to flexure. In the meantime, since the bending has increased, the actual pressure between the two has also materially increased, with a corresponding increase in the depression.

Having followed the changes that take place in the beam up

to the instant that its inertia has been entirely overcome, we are now in a position to determine the external moments that set up the stresses producing failure.

Considering the forces acting on the tup, there is, first, the force of gravity giving it a downward acceleration g, and, second, an upward force p, the pressure of the beam imparting acceleration in the direction opposite to motion and equal to a. If s stands for the vertical displacement of the tup then $\frac{d^2s}{dt^2}$ represents the rate at which the tup is changing its velocity; that is, the acceleration of the tup, which, it has just been seen, is the resultant of a upward and g downward. Since the motion of the tup relative to the centre of the beam is extremely small, being due only to a change in the indentation, $\frac{d^2s}{dt^2}$ is also the acceleration of the centre beam. Besides these major forces, there remain, of course, friction of the tup in its guides and air resistance. Tests made to find the change in velocity due to friction showed that the velocity was not decreased more than 2 per cent., indicating that friction is quite small when compared to the force of gravity and absolutely negligible when compared with the upward force of the beam.

Put as an equation, these conditions are expressed by the relation

$$\frac{ds^2}{dt^2} = a - g$$

or

$$a = g + \frac{d^2s}{dt^2}$$

If p represents the pressure exerted by the beam upward in pounds, W_t the weight of the tup in pounds, and a and g accelerations in feet per second we have

$$p = \frac{W_t}{g}\, a = W_t + \frac{W_t}{g}\frac{d^2s}{dt^2} \qquad (1)$$

Proceeding now to the energy-work relations, we obtain the general energy equation:

$$\int (ds - dy)p + \int F dy + \int \frac{W_b}{2g}\, u^2 + \tfrac{1}{2}\frac{W_t}{g} v^2 + E_e$$

$$= \int W_t\, ds + \int \delta W_b z + \tfrac{1}{2}\frac{W_t}{g} v_t^2 \qquad (2)$$

Work done up to any instant plus kinetic energy at that instant is equal to the initia kinetic energy plus work available.

$\int (ds-dy)p =$ work done in compressing the fibres at the point of contact of the tup, s being distance passed through by the tup, y the distance the centre of gravity of the beam passes through, and p the pressure between the tup and the beam. The difference between y and s is usually less than ½ of 1 per cent. of the total deflection, so that the work lost in denting the beam is negligibly small and will be neglected in the subsequent discussion.

$\int F dy =$ work done in deflecting the beam. The force F is practically identical with the pressure p, and would be exactly the same as p for weightless beams. F is in the determination of this force that the main problem of stresses in beams subject to impact lies. F is equivalent to the centre load in a static bending test, which, when plotted against deflections, gives a curve from which the modulus of elasticity, the modulus of rupture, and the energy of rupture may be computed.

$\int \frac{\delta W_b}{2g} \mu^2 =$ kinetic energy of the beam, where W_b is the weight of the beam and μ the velocity of any element δW_b[1].

$\frac{1}{2} \frac{W_t}{g} v^2 =$ kinetic energy of the tup at any instant under consideration after initial contact, W_t being the weight of the tup.

$E_e =$ energy lost in vibrations. In all impact some energy is lost in vibrations, but this can be largely reduced by making the ratio of the weight of the machine frame to that of the tup relatively large[2]. It will be omitted on this basis.

$\int W_t ds =$ work done by gravity on the tup after initial contact with the beam.

$\int \delta W_b z =$ work done by gravity on the beam after initial contact, z being the deflection of the element δW_b.

$\frac{1}{2} \frac{W_t}{g} v_t^2 =$ kinetic energy of the tup at the instant of contact, v_t being the velocity of the tup at that instant.

While equation (2) is general and applies at any instant dur-

[1] Merriman's "Mechanics of Materials," p. 335.

[2] See article on the "Theory of Impact," by Harry D. Tieman, in the JOURNAL OF THE FRANKLIN INSTITUTE, vol. 168, p. 244.

ing the motion, the energy that exists as vibrations will be relatively large for the first part of the deflection during the time required to overcome the inertia of the beam. Consequently the subsequent discussion will concern the motion after the vibrationless condition has been more nearly reached.

Referring again to the integral $\int F dy$, it will now be observed that the work of deflection is equal to the change in kinetic energy of the tup plus the work done by gravity on the tup and beam during deflection, minus the energy lost in imparting velocity to the beam and denting it at the point of contact.

Bearing in mind that v is the velocity at the centre after the inertia of the beam has been entirely overcome, and u is the corresponding velocity of any element δW_b, away from the centre, it is a simple matter to express u in terms of v, since the elastic curve is assumed to be known. Let l be the length of the beam, y' and z', y'' and z'' be the corresponding deflections at the centre and at any section distant x from the end, respectively, and let P' and P'' be the loads at the centre corresponding to y' and y''. Since the load at the centre is directly proportional to the deflection at the centre, or at any other point with the elastic limit

$$\frac{y'}{y''} = \frac{P'}{P''} = \frac{z'}{z''}$$

$$\frac{y'' - y'}{y'} = \frac{z'' - z'}{z'}$$

But $y'' - y' = dy$, and $z'' - z' = dz$, hence

$$\frac{dy}{y'} = \frac{dz}{z'}$$

$$\frac{dy}{dt}\,\frac{1}{y'} = \frac{dz}{dt}\,\frac{1}{z'}$$

$$\text{or } \frac{v}{v'} = \frac{u}{z'} \qquad \text{and } u = v\,\frac{z'}{y'}$$

The deflection at any section distant x from the left end of the beam is

$$z' = \frac{P'}{48EI}\,(3l^2x - 4x^3)$$

The deflection at the centre for the same load P' is

$$v' = \frac{P'l^3}{48EI}$$

It follows that

$$u = v\,\frac{(3l^2x - 4x^3)}{l^3}$$

We are now in a position to evaluate two of the integrals.

$$\int \frac{\delta W_b}{2g}\,u^2 = \frac{W_b v^2}{gl^3}\int_0^{\frac{l}{2}} (3l^2x - 4x^3)^2 dx$$

$$= \frac{17}{35}\,\frac{W_b}{2g}\,v^2$$

Also

$$\int \delta W_b z = \frac{2W_b P}{48EIl}\int_o^{\frac{l}{2}} 3l^2x - 4x^3)dx$$

$$= \frac{5}{8}\,W_b y \qquad \text{since } \frac{1}{48}\,\frac{Pl^3}{EI} = y$$

Inasmuch as the average weight of the beam is only four pounds and the work done by gravity in deflecting it is only $\frac{5}{8} \times 4 \times y$, while the work done by the descending tup will average $800y$, the error introduced by omitting this integral is also very small. Moreover, since one of the purposes of the discussions is to make a comparison between the energy of rupture for static and impact bending, and the former test disregards the work done by gravity on the beam, it will also be neglected here.

There results, then, upon replacing in equation (2) the integrals valuated, the new equation

$$\int F dy + \frac{17}{35}\,\frac{W_b}{2g}\,v^2 + \frac{1}{2}\,\frac{W_t}{g}\,v^2 = W_t y + \frac{1}{2}\,\frac{W_t}{g}\,v_t^2$$

For any one height of drop v_t is a constant, hence on differentiating

$$\frac{Fdy}{dt} + \left(W_t + \frac{17}{35}\,W_b\right)\frac{v}{g}\,\frac{dv}{dt} = W_t\,\frac{dy}{dt}$$

But

$$\frac{dy}{dt} = v' \quad \text{and } \frac{dv}{dt} = \frac{d^2y}{dt^2} = \frac{d^2s}{dt^2}, \text{ so that}$$

$$Fv + \left(W_t + \frac{17}{35}\,W_b\right)\frac{v}{g}\,\frac{d^2s}{dt} = W_t v$$

$$F = W_t - \left(W_t + \frac{17}{35}\,W_b\right)\frac{1}{g}\,\frac{d^2s}{dt^2} \qquad (3)$$

From the last equation it is seen that the beam must exert a force upward that will overcome the weight of the tup and impart to a mass of $\left(W_t + \frac{17}{35} W_t\right)$ pounds an acceleration $\frac{d^2s}{dt^2}$.

The latter should be noted in particular, for it shows that the beam impart an acceleration not only to the tup but to forces in the beam also. This is obvious when one remembers that at the instant when the inertia of the beam has been overcome, which happens very soon after initial contact, the beam has acquired a considerable velocity, and this velocity is reduced to almost zero at the time of maximum deflection. These forces proceed, of course, from the elastic deformation of the fibres.

The force F being a centre force acting on a simple beam supported at the ends, the external or bending moment is obtained immediately, and equating to the internal or resisting moment there results

$$\frac{Fl}{4} = \frac{SI}{v} \qquad \text{(Within the elastic limit)}$$

$$\text{or} \qquad S = \frac{Flv}{4I} \qquad (4)$$

Where S = fibre stress desired,

$\frac{I}{v}$ = section modulus of the beam,

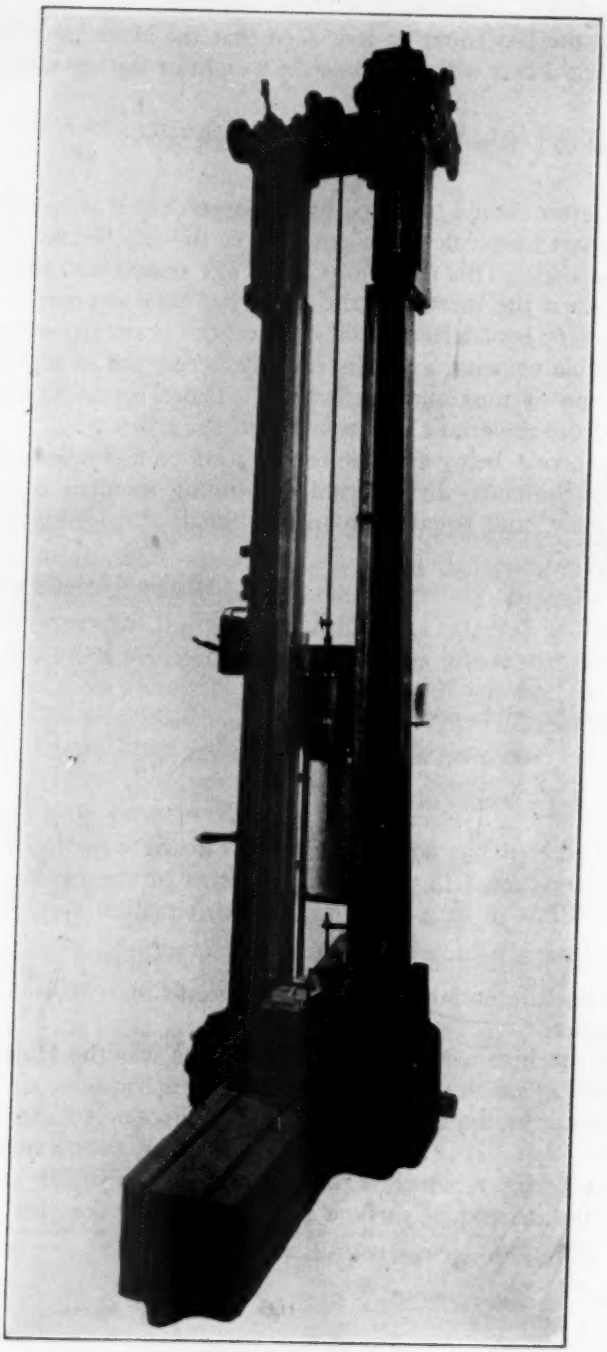
l = length of the beam.

The problem has now resolved itself down to finding the value of F in equation (4), all the other terms of the equation being known. This in turn takes us back to equation (3), in which all the terms are known except the acceleration $\frac{d^2s}{dt^2}$. A double differentiation of the deflection-time curve yields the acceleration.

The machine used for making the tests was the Hatt-Turner drop testing machine,[3] having a maximum capacity of 72-inch drop, in use by the United States Forest Products Laboratory at Madison, Wis. It is provided with a cylinder, shown mounted in position in Fig. 1, which is rotated at a relatively high speed and has wound around its surface a metalized sheet for receiving the

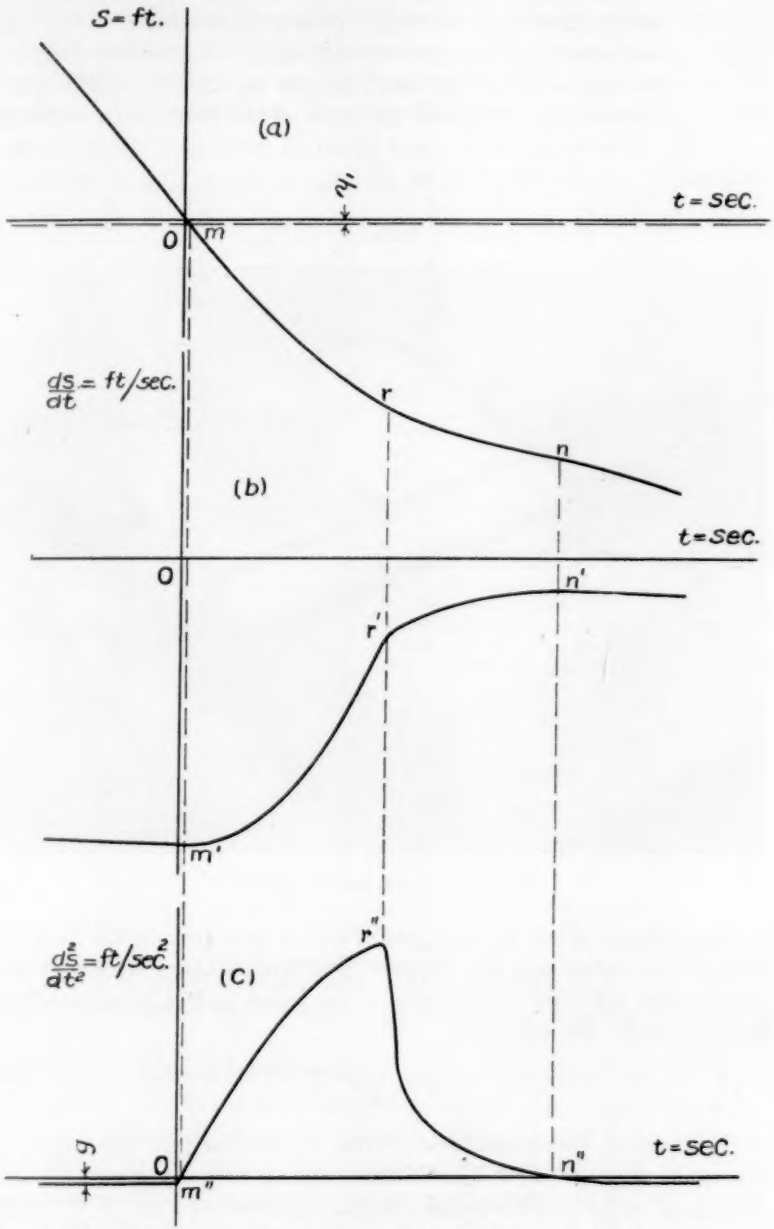
[3] A. S. T. M. Proceedings, vol. 6, p. 462.

FIG. 1.



Hatt-Turner drop impact testing machine

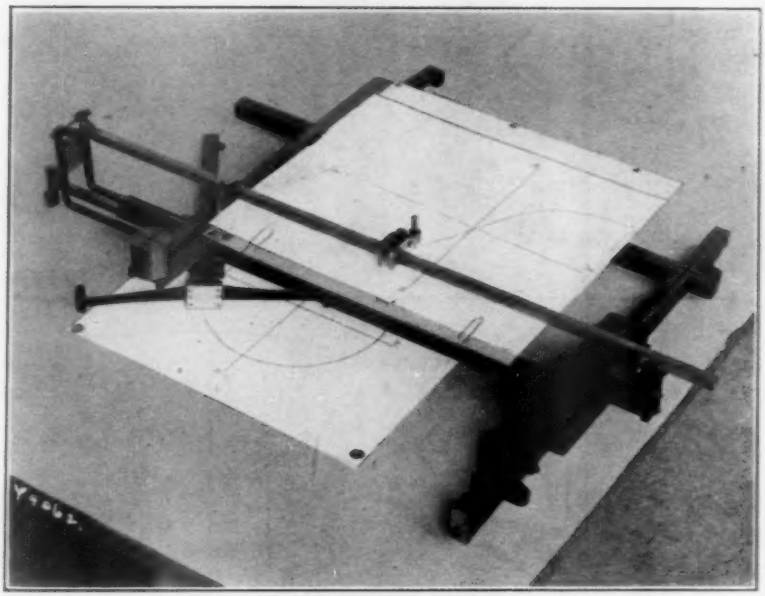
FIG. 2.



A typical time-deflection curve from impact test on a timber beam, and its first and second differential curves.

impression of the stylus fixed to the descending tup. A zero or base line is first drawn on the sheet, giving the position of the tup when it rests upon the beam as a static load. An electric contact releases the tup when it has been drawn up the desired height, and a tuning-fork record gives the scale of the abscissa in seconds per inch. The latter record was taken to serve as a check on the theoretical velocity attained by the tup at the instant of striking.

FIG. 3.



The author's differentiating machine.

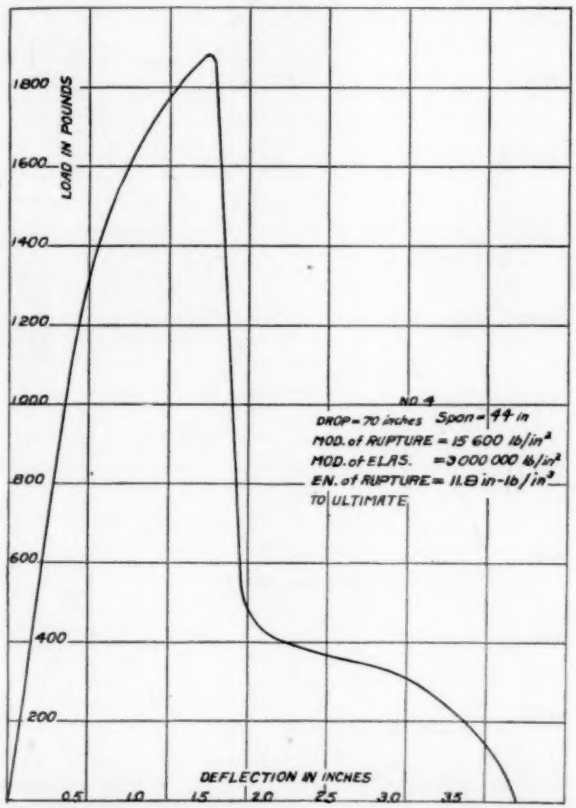
Deflections must be measured from a base line of no load, so that it was necessary to compute first the distance up from the line drawn with the tup resting on the beam to the position of no deflection, by the equation

$$y_1 = \frac{1}{48}\frac{W_0 l^3}{EI}$$

A typical deflection-time curve as obtained in the tests is shown in Fig. 2 (*a*). The differential or velocity curve of (*a*) is shown as (*b*) immediately below, and the second differential

or acceleration curve is shown at (*c*). The dashed horizontal line represents the base line drawn on the paper while mounted on the cylinder with the tup resting on the beam, and y_1 is the static-load deflection computed according to the method mentioned. Deflections are likewise distances of descent, *s*, of the

FIG. 4.

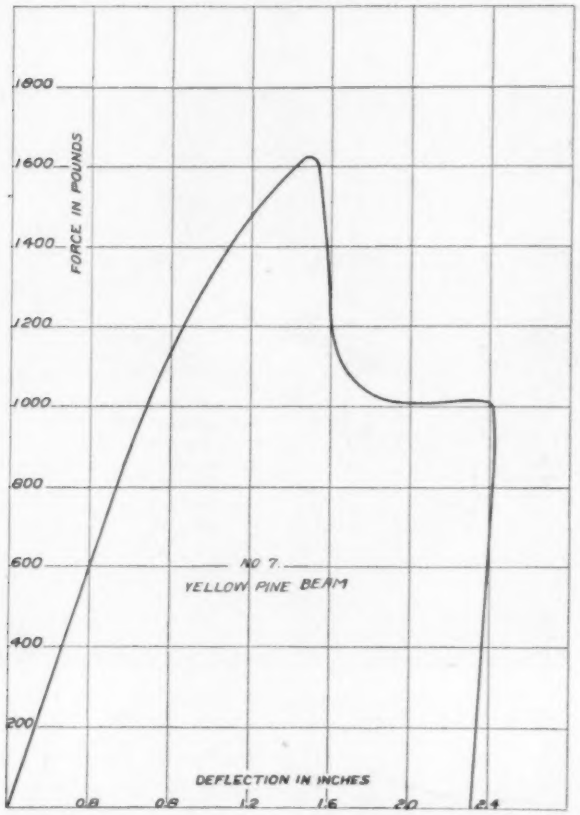


Impact force-deflection curve for a long-leaf yellow pine beam completely ruptured by a single blow.

tup, except at the start when the inertia of the beam has not been overcome. Up to the point where the curve crosses the time axis, the tup is falling freely under the influence of gravity, the velocity increasing in the downward direction proportional to the time, and the acceleration remaining constant, being equal to *g*, the

acceleration of gravity. At *m* (neglecting inertia at the beam) the curvature changes, indicating a change in direction of the acceleration from negative to positive values. At *r* failure occurs and the acceleration curve shows a sudden drop. Rupture is not yet complete, but proceeds up to the point *n*. Here again there is

FIG. 5.



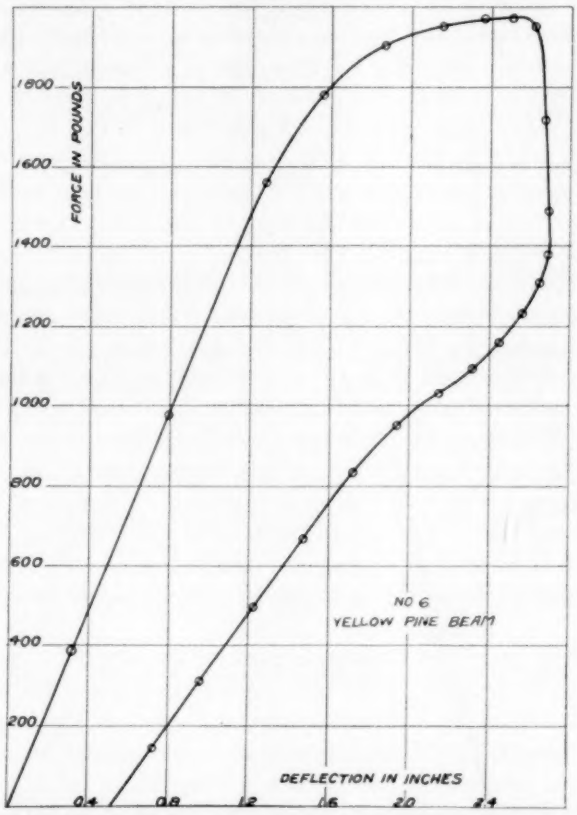
Impact force-deflection curve for a long-leaf yellow pine beam fractured but not entirely ruptured.

a change in curvature of the space-time curve, signifying a change in the direction of the acceleration, which again becomes negative; and thereafter the body falls through the action of gravity alone.

Accelerations being the quantities desired, it is necessary to go through this process of differentiation for each curve, draw-

ing first the velocity-time curve and then its differential by finding the slopes at a series of points on each curve, and plotting these slopes as ordinates to a new base line. This was done mechanically by means of the author's differentiating machine shown in Fig. 3.[4]

FIG. 6.



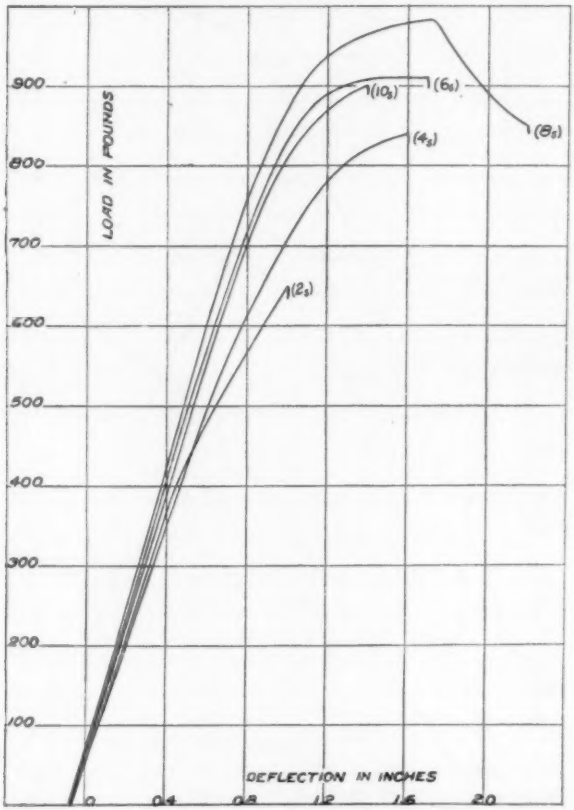
Impact force-deflection curve for a long-leaf yellow pine beam fractured but retaining considerable resilience. The circles space off equal time-intervals.

After computing the scales of each of the curves, we are in a position to draw the load or force-deflection curves for impact. By dividing the time axis into small units, finding the acceleration corresponding to each time interval, substituting in equation (3)

[4] For a description of the differentiator, refer to *Scientific American Supplement*, Feb. 12, 1916, or *The American Mathematical Monthly*, October, 1916.

to get the effective centre force F, and then scaling the deflections corresponding to each of these accelerations (hence forces), and plotting these values of force and deflection on coördinate axes, we have the desired force-deflection curve. A typical curve obtained in this manner is shown in Fig. 4. The beam was thor-

FIG. 7.



Load-deflection curves for Douglas fir beams in static cross-bending.

oughly air-dried long-leaf pine of a 2 x 2-inch section and span of 44 inches. The point of failure, as will be noted, is very pronounced, followed by continued deflection, in which the fibres that were not completely ruptured at the first failure are torn or crushed progressively.

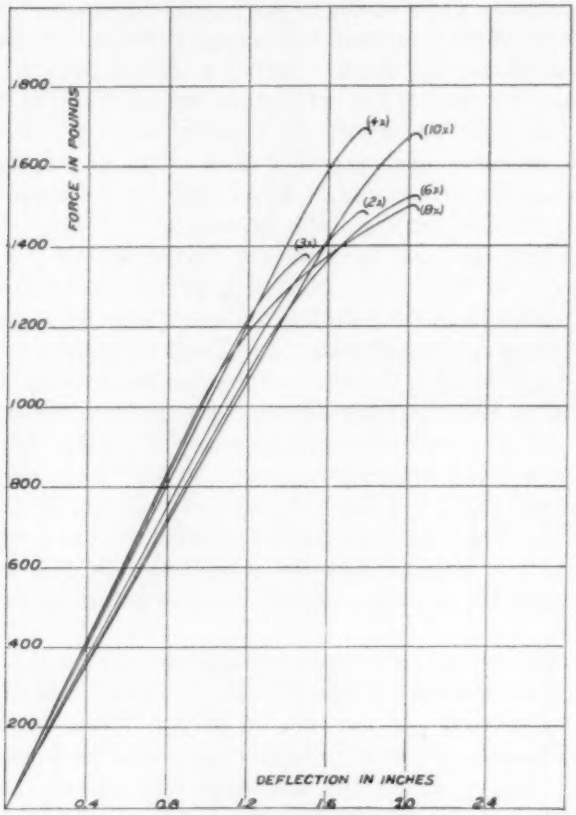
Figs. 5 and 6 show the curves for two beams not completely

ruptured, each retaining sufficient resiliency to send the tup back after the maximum deflection had been reached. The beam of Fig. 5 is peculiar in that initial failure was followed by an increase of deflection in which the load remained practically constant, indicating that the fibres failed at a rate just sufficient to balance the increase in force due to increase in deflection. At maximum deflection the total available energy had been consumed, and almost simultaneously there occurred a second failure. But the tup had already reversed its motion, as indicated by the returning curve. The latter phenomenon occurred more strikingly in the beam whose curve is shown in Fig. 6. The circles distributed along this curve are spaced at equal time intervals apart. Evidently, as the time increases, the stresses in the fibres tend to give away, causing the curve to bend over during the latter part of the sweep up to the ultimate. Motion is extremely rapid, the time between two successive points being only 0.00167 second. The values of stress at the ultimate, the so-called modulus of rupture, computed according to the flexure formula, the modulus of elasticity, the energy consumed up to the ultimate, and the deflection to the ultimate are all tabulated in the summary of results on page 788. The stresses found range from 10,000 lb./in.^{2} to 22,000 lb./in.^{2}, values considerably in excess of those of ordinary cross-bending tests. The difference in moduli of elasticity is not quite so pronounced. The large values for stress may be due in part to selected material, but more probably to the nature of the loading itself.

For the purpose of a more reliable comparison between impact and static stresses, a heavy board of Douglas fir of uniform grain was selected and cut into strips for beams so that every alternate beam was tested in impact and those between in cross-bending. Fig. 7 shows the load-deflection curves for the five beams tested in ordinary static cross-bending. Fig. 8 shows the groups of six impact force-deflection curves, each of which was obtained by going through the entire process described. The curve after the ultimate had been passed was omitted in grouping them in order to avoid confusion. Bearing in mind that each curve was developed independently, without any knowledge of the scale to which the previous ones were graphed, since the scales were not computed until all the differentiation had been completed, it is rather a remarkable fact that the curves lie so close

together and their ultimates are so nearly equal. The results for Douglas fir are summarized in the composite curves of Fig. 9, and for comparison the values are tabulated in Table II. From this it will be seen that the stresses set up in impact and the energy

FIG. 8.



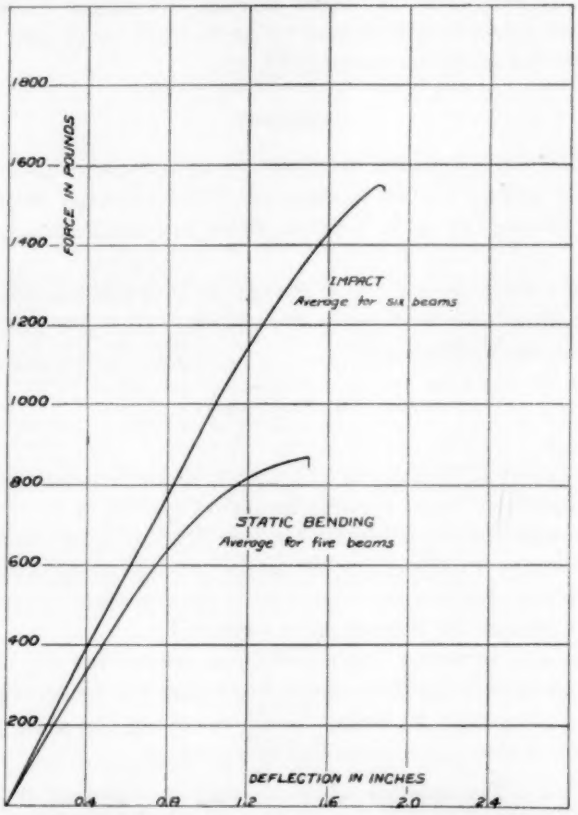
Impact force-deflection curve for Douglas fir beams ruptured by a single blow. Curves shown up to ultimate load only.

consumed are almost double the corresponding values in static bending.

To test for losses of energy the areas under the load deflection curves were each obtained with a planimeter. For the beams not completely ruptured,—that is, in which the tup came to a standstill, and may possibly even have been returned,—the work consumed by the beam to the maximum deflection is the area under the

load-deflection curve in foot-pounds. This must equal the total energy available (neglecting loss due to vibration and crushing of fibres); that is, the initial kinetic energy of the tup plus the work done by gravity on the tup during the deflection. Similarly, the area under the load-deflection curve for those beams that were

FIG. 9.



Composite load and force-deflection curves for Douglas fir.

completely ruptured is the energy consumed and is equal to the difference between the kinetic energy on initial contact and the energy at rupture, plus the work done by gravity during the deflection. The results of this comparison are tabulated in Table III, the negative sign indicating that the area under the curve was greater than the total work available, which is clearly impossible,

showing a slight inaccuracy in the work of differentiation or measurement. The average of all the differences is a little less than 1 per cent. This difference is well within the limits of accuracy of the differentiation, although it may also be accounted for by the energy lost in crushing the fibres. Probably the most significant conclusion that can be drawn from this low average error is the fact that the losses due to vibrations, hitherto unknown and sometimes assumed to be as high as 25 per cent. of the energy available, are practically zero.

SUMMARY.

1. Fibre deformations in impact set up forces which overcome the kinetic energy of the tup and the kinetic energy acquired by the beam during the short impulse period immediately after initial contact.

2. By setting up a general energy-work equation for impact, differentiating, and dividing by the velocity, an expression for the effective force was obtained:

$$F = W_t + \left(W_t + \frac{17}{35} W_b\right) \frac{1}{g} \frac{d^2s}{dt^2}$$

3. Double differentiation of the time-deflection curve obtained autographically yielded the acceleration-time curve.

4. By substituting values of the acceleration from the acceleration-time curve in the equation for F and plotting against the corresponding deflections from the deflection-time curve, force-deflection curves for impact were obtained.

5. From a series of force-deflection curves for six beams of Douglas fir broken under a single blow and five beams broken in static cross-bending, all beams being cut from the same piece of timber, the following conclusions were drawn:

(*a*) The impact fibre stresses are almost double the slow bending stresses, at rupture.

(*b*) The energy of rupture in impact up to the ultimate load is twice that of static bending.

(*c*) The deflection at the ultimate load and the modulus of elasticity are about one-fourth higher for impact than the corresponding properties under static loading.

6. The mechanical properties of long-leaf yellow pine and spruce are higher in impact than the average values for the same properties in static bending.

7. The energy available is practically entirely consumed by the beam, supporting the contention that very little energy is lost in vibrations of the machine frame.

TABLE I.

Log of Impact Tests on Timber Beams.

No.	Kind of timber	Span, inches	Dimensions in inches	Drop of tup in inches	S Modulus of rupture, lb./in.	E Modulus of elasticity, lb./in.	Energy consumed to ultimate in in-lb/in³.	Deflection to ultimate, inches
1	Yellow pine	50	2 x 2 x 52	36	10,200	2,150,000	4.76	1.44
2	Yellow pine	50	2 x 2 x 52	48	22,200	4,000,000	11.8	1.60
3	Yellow pine	44	2 x 2 x 46	65	16,900	2,700,000	14.0	1.70
4	Yellow pine	44	2 x 2 x 46	70	15,600	3,000,000	11.8	1.50
5	Yellow pine	50	2 x 2 x 52	60	16,000	2,600,000	15.0	2.48
6	Yellow pine	50	2 x 2 x 52	70	17,750	2,500,000	17.3	2.50
7	Spruce	44	2 x 2 x 46	48	13,500	2,000,000	8.2	1.50
2x	Douglas fir	50	2 x 2 x 52	44	14,000	1,850,000	6.8	1.72
3x	Douglas fir	50	2 x 2 x 52	50	13,000	2,000,000	5.5	1.46
4x	Douglas fir	50	2 x 2 x 52	40	15,900	2,000,000	7.7	1.74
6x	Douglas fir	50	2 x 2 x 52	48	14,400	1,800,000	8.7	2.04
8x	Douglas fir	50	2 x 2 x 52	48	14,100	2,000,000	9.8	2.04
10x	Douglas fir	50	2 x 2 x 52	44	15,800	1,760,000	9.2	2.04

Weight of tup = 50 lb. Average weight of beam = 4 lb.

TABLE II.

Comparison of the Mechanical Properties of Douglas Fir in Impact and in Static Bending.

DOUGLAS FIR.

A = Average values for impact test on six beams.
B = Average values for static bend test on five beams.

Average values	*A* Impact test	*B* Static test	Ratio *A*/*B*
Maximum load in pounds	15,500	870	1.78
Deflection at ultimate, inches	1.84	1.50	1.23
Modulus of elasticity, lb./in.²	1,920,000	1,600,000	1.20
Modulus of rupture, lb./in.²	14,500	8,150	1.78
Energy consumed to ultimate, in-lb./in.³	7.94	4.00	1.98

TABLE III.

Comparison of the Energy Available and the Energy Consumed by Beams Broken in Impact.

No.	Kind of timber	*A* Energy available, foot-pounds	*B* Area under Force-defl. curve, foot-pounds	Per cent. difference between *A* and *B*
1	Yellow pine	145.7	138	5.28
2	Yellow pine	207.2	208	−0.4
3	Yellow pine	250	252	−0.8
4	Yellow pine	270.7	262	3.2
5	Yellow pine	273.8	264.7	3.3
6	Yellow pine	291	304	−4.5
7	Spruce	201	201	0.0

The Use of Titanium in the Manufacture of Steel Castings. W. A. JENSSEN. (*Proceedings of the American Foundrymen's Association*, September 11–15, 1916.)—Notwithstanding all that has been said regarding the harmful effects of phosphorous and sulphur in steel castings, occluded gases and oxides are the real causes of many of the troubles of the steel foundryman. In the elimination of these difficulties, ordinary dioxidizers such as ferro-manganese and ferro-silicon have their place, but if the best results are to be achieved a more potent reagent is necessary, and for this purpose ferro-titanium has proved unusually satisfactory. Titanium undoubtedly is one of the most powerful dioxidizers and denitrogenizers known. The chief value and merit of titanium lies in its positive action in the removal of occluded oxides, nitrogen and entrapped slags. The present-day method of using ferro-titanium is to augment the incompleted cycle of reactions with ferro-titanium after the other deoxidizers have been added. Ferro-titanium additions are of value to the foundryman in making low or high-carbon or alloy steels. The results are not due to any direct or alloying effect of the titanium, but rather to its value as a deoxidizer and cleanser in removing harmful occluded gases and slags. Titanium, however, must not be looked upon as a cure-all to rectify the evils of poor stock selection and bad furnace practice. Its function is to make good steel better. In these days of high priced ferro-manganese, ferro-titanium can be used to advantage to decrease the consumption of the manganese alloy.

A NATIONAL DEPARTMENT OF PUBLIC WORKS OUR NATION'S NEED.*

BY

ISHAM RANDOLPH, D.Eng.

Member of the Institute.

SINCE the Franklin Institute *is*, as the philosopher and patriot, whose name it memorializes, *was*, concerned with all of the arts and sciences and with all movements, which are in their essence for the betterment of mankind in general and of the American people in particular, I make bold to offer for the consideration of its faculty and members a suggestion which is fraught with vast possibilities for good to the American nation. That suggestion I present in the form of a bill for the creation of a new department of government to be known as the National Department of Public Works. Observations resulting from personal contact with the various agencies which now conduct the Public Works of the United States, extending over a period of about thirty years, have served to convince me that these various agencies should give place to centralized authority, and centralized responsibility. My crystallized convictions find expression in the following bill:

A BILL TO CREATE AND MAKE EFFECTIVE A NATIONAL DEPARTMENT OF PUBLIC WORKS.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled:

That the creation of a Department to be designated and known as the Department of Public Works of the United States is hereby authorized. The head of this Department shall be designated as the Secretary of the Department of Public Works and he shall be appointed by the President of the United States with the consent of Senate thereof and he shall be a member of the President's Cabinet.

The first duty of the Secretary of the Department of Public Works shall be to perfect a working organization for the purpose

*Communicated by the author.

of carrying on all of the public works of the United States other than those which pertain to National Defense or work wholly relating to navigation and light house construction and service.

He shall appoint a Commissioner of Public Works who shall be a man of recognized ability and successful accomplishment along lines of engineering science and construction.

This election and appointment shall be made with the full knowledge and approval of the President of the United States and the man so appointed shall hold office until disqualified by physical or mental infirmity, old age, moral delinquency or demonstrated unfitness. In consultation with the Secretary, the Commissioner of Public Works shall organize office and field forces sufficient in number and suitably qualified to carry out the intents and purposes of this act, which are as follows:

To carry to completion all constructive works, such as public buildings, levees, dams, roads, bridges, structures and improvement works of every description and kind authorized and provided for by Congress and placed under the jurisdiction of the Department of Public Works.

To secure physical data pertaining to rivers, swamps, arid regions, to procure existing maps showing the natural and political divisions of the United States and its territorial and insular possessions.

To secure copies of all topographical maps of accepted reliability and to make topographical surveys of all areas under the control of the United States within which accurate knowledge of the earth's surface seems either necessary or desirable.

To study the meteorological data which has been accumulated by Governmental or other agencies with a view to determining flood expectancy.

To study the characteristics and capacities of the streams of the country for the purpose of determining what had best be done, and how, to avert flood disaster.

To select suitable reservoir sites for storing flood waters with the purpose of lowering the flood planes of streams and later, releasing the waters so stored for the purpose of aiding navigation during dry periods and emptying the reservoirs in advance of recurring excessive precipitation.

To study those drainage problems which by reason of civil divisions are interstate in their scope, and to devise plans for

draining swamps and overflowed lands in coöperation with States, Counties, Townships, or Municipalities upon an equitable basis of division of cost.

To select available sites for the development of water power.

To gather and preserve data relating to arid lands and the sources from which water may be secured with which to irrigate these lands.

To prepare plans for such structures as it may be necessary or desirable to build in carrying out the purposes of this bill as hereinbefore set forth, together with estimates of cost and recommendation relating thereto.

Those works to be first considered and reported upon, the importance or necessity of which has been demonstrated by disasters creating National sorrow and sympathy, for the purpose of reclaiming lands laid waste by such disasters and restoring them to the Nation's sources of wealth production and permanently thereafter preventing a recurrence of like disaster.

The Secretary of the Department, with the approval of the President, shall present to Congress at each session such projects as he deems meritorious and for which there seems to be an urgent need, together with estimates of cost and his recommendations thereon.

The Secretary shall present each year a report of the operations and expenditures made in accordance with the intent and purposes of this bill and he shall prepare and present a budget setting forth the financial needs of his department, both for administration and constructive work for the fiscal year next ensuing.

The salary of the Secretary of the Department of Public Works shall be the same as that of the Secretary of War, and the salaries of the employees of the Department shall be determined by the Secretary with the advice of the Commissioner of Public Works and the approval of the President.

All coastal harbors shall remain as now in charge of the War Department. All navigable rivers above their harbor entrances shall be under control of the Department of Public Works.

All projects for improving waterways and for protecting adjacent lands and properties from damage due to shifting river channels or to overflow in times of flood, originated by persons, corporations, communities or municipalities, must be submitted

to the Secretary of the Department of Public Works and receive his approval before any of the work contemplated in the project is entered upon.

Where projects dependent upon Federal coöperation and financial aid are presented, the extent of that coöperation and the measure of financial aid must be passed upon by the Secretary of the Department of Public Works and he must submit his conclusions and recommendations to Congress.

The execution of any and all projects in which the Government coöperates shall be under the direction and control of the Department of Public Works.

The transfer of the several bureaus or departments now engaged in carrying on the various classes of work which it is the purpose of this act to place under the control of the Department of Public Works, shall be made in such manner as not to hinder or retard any necessary work now in progress; but the transfer shall be made as speedily as is consistent with this requirement, and all such transfers shall be completed within one year from the date of the passage of this act.

To defray the expense of organizing the Department of Public Works of the United States and to maintain the same until the Secretary submits the first budget setting forth the needs of the Department, the sum of Five Hundred Thousand (500,000) Dollars is hereby appropriated which shall be paid out of the treasury of the United States upon warrants drawn by the Secretary of the Department of Public Works.

This is the bill as it comes from a mind unskilled in statecraft, unversed in legislative nomenclature, and it is presented only as a suggestion for the lawmakers whose experience and learning qualifies them to build upon this suggestion, a law free from the imperfections which one would naturally look for in the work of an amateur.

Let us consider some of the arguments in support of the claim that a National Department of Public Works is a National necessity.

Not only did I present this bill to the Third Annual Convention of the National Drainage Congress, but I sent a copy to President Wilson. Also I presented copies to our Secretary of State, to our Secretary of Interior and to certain of our national

legislators. I received an acknowledgment from the President through his secretary. I talked with Secretary Bryan about it and he expressed the view that it would come at some future time, but that I would not live to see it. The Secretary of Interior, Mr. Lane, was most sympathetic and friendly to the idea. Senator Ransdell expressed his approval of the bill, but told me that unless I could get the country back of it, Congress would never touch it.

How can a lone civil engineer ever get the great American people to back up a proposition like this? Never can he accomplish it unless he can enlist great organizations like The Franklin Institute in a crusade to bring it about.

Men, of this great society, let me tell you why I think a National Department of Public Works is needed.

This great nation of ours finds out gradually what it needs. In its very genesis, it knew it needed a Department of State, for young as it was, it had to deal with the nations of the earth. It knew it needed a War Department, for it had by war won its way to independence and a place among earth's governments. It knew it needed a Treasury Department, for it must collect and disburse revenues, issue a medium of exchange and protect the country's credit. It knew it had to have a Department of Law, presided over by an Attorney-General, for it had to know and keep within the bounds of international law and to deal with interstate law affecting the interests of its citizens and those of the stranger within its gates.

Those were the four original departments having Cabinet representation.

The need for a Navy Department was manifest, for a navy had to be built up and maintained to protect its maritime commerce and to uphold upon the high seas the honor of its flag, but the demand for this was not met until 1798.

A post-office organization was kept up for thirty-five years before it was made a national department whose executive head was given a place in the Cabinet. This came to pass in 1828.

Its vast territory and the care of its wards, the aborigines, called for the exercise of particular and responsible supervision, and this call was met by the creation, in 1849, of the Department of Interior.

As time went by other needs developed; since from the soil

comes man's sustenance and wealth, just recognition of its importance was made by the creation in 1889 of the Department of Agriculture.

The growth of one hundred and fourteen years demonstrated the need of a Department of Commerce and Labor, and it was created in 1903. March 4, 1913, Commerce and Labor were segregated and now we have the Department of Commerce and the Department of Labor.

The heads of all these departments are members of the President's official family; they are his Cabinet advisors.

And now "in the fulness of time" another national need is recognized and its supply should not long be delayed. The need is for a National Department of Public Works.

The public works of the United States are vast in their scope and of immense importance. Some of the things that ought to be done are in process of accomplishment, but they are few in comparison to the needs of a land whose material advancement is held back because needed work along many lines is not even attempted. The work that is being done is not concentrated in one department under one responsible head, but apportioned off to several departments whose responsibilities and whose efforts are not correlated. The Treasury Department has charge of public buildings. Is there any correlation between scientific finance and scientific building? Does the training which fits a man to be at the head of the National Finances also fit him to pass upon architectural design and structural sufficiency?

The work of reclaiming arid lands, involving as it does vast engineering structures, is confided to the Department of Interior, as is the research work conducted by the Geological Survey. The Department of Agriculture is charged with the engineering involved in drainage investigations and road building. The War Department has charge of the national defenses as is eminently proper; there is the appropriate field for the military engineer. But it also has charge of all the rivers and harbors of the United States and its acquired territory, together with the building of all canals, the cost of which is defrayed by the nation.

Now these activities are carried on by the several departments named, each independent of the other, without correlation or coöperation, and it ought not to be so. These activities should all be aggregated in one department under one responsible head who

should be a member of the President's Cabinet and the peer of his fellow-members.

Then, and not until then, will proper plans, upon broad and comprehensive lines, be worked out and carried persistently to a conclusion which will give results commensurate with the public need and worth the vast expenditure of the people's money.

What we need is a plan big enough to compass the land and so well considered that the work most needed can be first begun and, when it is finished, it will be so much accomplished in the development of the great comprehensive project; and so let each successive component section of the plan be taken up in the order of its need until the last section is reached and the mighty work stands complete; a monument to the brains that planned and the energy, skill and well-applied labor that accomplished all. Such a work as this is not for a decade or a lifetime, but to be carried forward long after its designers have been gathered to their fathers.

But it is not necessary to fold our national hands and wait until this vast plan is all worked out and presented to the Nation. There are things to be done now, so obvious and so necessary that they are at once recognized as integral parts of any great comprehensive plan.

The vastness of the land suggests the immensity of the plan which must be evolved to meet its needs. The continental holdings of the United States, including Alaska, are given as 3,742,583 square miles. Within the United States proper, there are 26,410 miles of navigable rivers, 75,000 square miles of swamp lands and 1,200,000 square miles of arid lands. The entire coast line of continental United States and its insular possessions is given as 48,881 miles. There is a field of operations which must arouse patriotism and stir ambition. These rivers must be improved and made more useful to the commerce of the land. They must be given a capacity adequate to carry the floods which vast water sheds pour into them, or where possible, the intensity of these floods must be abated by partial storage in reservoirs which will give up their stored waters when stream conditions render it safe to release them; that release being subject to judicious control. And, wherever possible, these streams must be made to yield all the power that head and volume of flow can generate.

These 75,000 square miles of swamps must be recovered; the

soil wealth which has been accumulating for "time out of mind" must be taken from the frogs and the reptiles and given to man for tillage with an assurance that no "garden of the Lord" ever yielded a richer bounty Those 1,200,000 square miles of arid lands must be made to fulfill the prophecy of Isaiah, "the desert shall blossom as the rose." For the sons of America will need all of these lands as the 100,000,000 of to-day will be 200,000,000 at no far distant to-morrow, and the increase will go on until there is no place in the whole land without an inhabitant. Is it too soon to begin doing all of these things with energy and zeal? We know that the delay has been too long already. And yet our lawmakers hang back.

In what I am about to say, I wish to make clear in advance that my remarks are not actuated by hostility to the United States Engineer Corps, for every citizen of the United States must be proud of the record these men have made and admire the integrity of an organization which has been a distinguishing characteristic of these splendid men. I speak more particularly of them because the horizon of their work is only bounded by the horizon of the country that they serve.

For more than thirty years I have been in contact with the men of the Corps of United States Engineers and I know their virtues, which are many, and their failings, which are few; failings theirs by reason of their humanity and not because of their training. I have throughout these years been on the opposite side of nearly every question which has brought me in contact with them and as a result I have learned to love these my constructive enemies. I have found them firm in their convictions, though, from my standpoint, often narrow in their views, loyal to their duty and their corps and honorable in their dealings. I fault not their efficiency, but their numerical inadequacy.

I find in "Form 87, War Department, Office of Chief of Engineers, Washington, January, 1916," a statement showing the rank, duties and address of the officers of the Corps of Engineers, U. S. Army, that there are but 232 engineers of that corps in active service. Of these, eleven are in the Philippines, four in Hawaii, ten on the Panama Canal and twelve are detailed as instructors and two are on Legation duty. This leaves 193 men, and of that number 64 are First Lieutenants and 28 Second Lieutenants; now lieutenants are about as capable of taking charge of public

works as are the young graduates from our engineering universities, and he would be truly confiding who would trust one of these fledglings with an important piece of construction; so that the available U. S. Engineer Corps is whittled down to one hundred and one experienced men and from that number must be subtracted the men whose duties are connected with the office of the Chief Engineers and the War College in Washington. The distinguished remainder cannot cope with the requirements of 26,410 miles of interior waterways, 48,881 miles of seacoast, national fortifications, government canals and miscellaneous work. These works must go on and the numerical deficiency must be made up from the ranks of the civilian engineers. The natural, the inevitable, result is that the engineering of the United States is mainly done by civilian engineers. The military engineer too often becomes an executive officer, affixing his signature, *pro forma,* to plans in the preparation of which he has had very little hand.

In the thirty-six years that I have lived in Chicago, there have been ten United States Engineers in charge of the work of that district, one of these, W. L. Marshall, later justly honored as Chief of Engineers, was in charge of the Chicago District for eleven years, and during all of that time there has been but one civilian assistant engineer in subordinate charge. About the time that an engineer officer has been inducted by his civil assistant into his duties and really becomes master of conditions and cognizant of the needs of a district, he is—like the Methodist minister—moved to a new field of duty.

Nor is this the worst of it. Genius in the United States Engineer Corps is cramped and initiative is repressed, these men must not originate; they may and do recognize needs in the Districts to which they are assigned, but suggestions are not welcomed in Washington. Until Congress orders investigations and reports, the army engineer may not ascertain facts (or if he does, he must keep them to himself) nor report conclusions. All of this reacts upon the civilian assistants; they become routine men, doing what they are told faithfully and well, but they soon part with all idea of initiative.

The natural result of this shortage of United States Engineers is delay in carrying on work which they are called upon to perform—in addition to regular duties—as members of Engineering Commissions. I will make a citation or two in support of this

statement and I wish it distinctly understood that I have no thought of censure for the men who compose the commission of which I speak.

In 1902, Congress ordered surveys, estimates and a report on a fourteen-foot waterway from Chicago to St. Louis, and provided $200,000 to defray the cost of it. The commission to whom this work was intrusted was composed of distinguished engineer officers. They employed parties of civilian engineers, in direct charge of a civilian engineer, and put them into the field to ascertain the facts. The surveys were made; the data thus secured was compiled and maps and profiles based thereon were prepared. The commission made its report in 1905, showing that the project was practicable; but, that in the judgment of the commission, there was no commercial justification for the building of the waterway. Later, for some reason, Congress called for another report on this same waterway extended to Cairo, and a board was formed composed of four military engineers and one civilian. This board had for its use all of the information secured by the previous board at a cost of $200,000 and all of the information collected by the Mississippi River Commission. It began its work in November, 1910. The report made by the board in February, 1911, as is shown by the last paragraph thereof, was not final, and certain features upon which it was required to report were not then covered. The final report of this commission was transmitted to Congress by the Secretary of War February 18, 1914, and became H. R. Doc. 762, 63rd Congress, 2nd Session. Why this delay of three years? Presumably because the members of that commission were so burdened with their regular duties that they had not time to bestow upon this superadded requirement. They were busy men and the things which had to be done they did, and left the matters which could wait until they could get around to them.

There are two features of the suggested bill that seem to me to be of especial importance; first, the appointment of a Commissioner of Public Works, "who shall be a man of recognized ability and successful accomplishment along lines of engineering science and construction . . . The man so appointed shall hold office until disqualified by physical or mental infirmity, old age, moral delinquency or demonstrated unfitness." Next, that requirement that the "Secretary of the Department, with the

approval of the President, shall present to Congress at each session such projects as he deems meritorious and for which there seems to be an urgent need, together with estimates of cost and his recommendations thereon."

The carrying out of this requirement would serve to correct an abuse which has led to scandal and waste. No project for a public improvement can now be reported on unless Congress orders it and getting Congress to order such a report becomes the task of the interests locally concerned in the improvement. These interests must secure influence sufficient to get their project a hearing and this makes business for lobbyists and gives the local Congressman a chance to make political capital by boosting the game. With such a department as is here advocated and such a requirement in the law creating it, a broad view of the whole national estate would be taken and the needs of every section of the country would be impartially presented upon the basis of merit and not of political expediency.

Just now the demand for National preparedness overshadows any appeal for a National Department of Public Works. Only a small percentage of our people realize the desirability of such a department, but the reverberation of the guns that make Europe tremble have thrilled all of our people and made us think of our defenselessness. To the south of us there has been a threat of war, which, had it come, would have contrasted with the death grips of the nations of Europe, as picket firing does with the thunders of battle joined. That threat, however, has served to demonstrate our need of trained soldiers and a system which will develop them. Let us hope that the sorry spectacle of a small fraction of one per cent. of our population responding to the call to the colors does not measure the patriotism of the men of the nation. War has become an engineering science. Soldiers are no longer commanded to hold their fire until they "can see the whites of the eyes of the enemy," but they must by engineering methods locate the positions held by the enemy, and gunners, who will never see those enemies, must by mathematical determinations so train their guns as to destroy those enemies, not only before "the whites of their eyes" are seen, but before their bodies even are discernible upon the distant horizon. In war, to-day, cold steel cannot be used until metal hot from the cannon's mouth and reheated by predetermined explosion has cleared the way for it.

It takes men of science to accomplish these modern miracles of destruction and the Army engineers are trained to work these miracles, as well as to build defenses which will set the miracle of defense against the miracle of destruction. We have too few men trained in the science of war; the few so trained should not be taken from the vocation for which they have been trained to fill positions for which they have no special fitness.

A National Department of Public Works would be a far step toward national preparedness.

Electrolytic Zinc Dust. H. J. MORGAN and O. C. RALSTON. (*Proceedings of the American Electrochemical Society*, September 28–30, 1916.)—The sudden increase in the price of zinc dust after the beginning of the European War, owing to the cutting off of the German and Belgian supply, led to the conducting of some experiments on the possibility of its production on a commercial scale from solutions of zinc, and the substitution of zinc made in this manner for the zinc dust ordinarily used in the precipitation of gold and silver in the cyanide process. The production of electrolytic zinc sponge seemed the most feasible method of accomplishing this object, the sponge to be of such a nature that it would crumble to dust when dried.

Sponge metal can be obtained from zinc sulphate solutions by the continual addition of a small amount of either copper or arsenic salts to the electrolyte. The objection to the use of zinc dust prepared by this method is the needless dilution of the bullion caused by the copper and the danger met in the handling of gold and silver precipitates when arsenic is used to produce the sponge. The preparation of zinc sponge is also possible from sulphate solutions by keeping acidity low and temperature high. Zinc oxide, rendering the solution slightly basic, is the most desirable chemical for maintaining this condition. It is subject to the objection that it is only slowly and slightly soluble in zinc sulphate solutions. The same objections apply to zinc sponge prepared from chloride solutions, except that the zinc sponge seems to be more inclined to be oxidized during drying. Sodium zincate solutions allow of the deposition of zinc sponge under a widely varying range of electrical and thermal conditions. Stirring of the electrolyte must be avoided. Current efficiencies of about 60 per cent. and zinc dust precipitating efficiencies of 70 to 75 per cent. are possible. There seems to be no difficulty in getting one pound of zinc dust from a solution of zinc with 3 kilowat-hours of energy. Sodium zincate solution recommends itself because of its ease of preparation from caustic soda and zinc oxide, both of which are articles of commerce. The zinc tenor of the solution can be maintained either by the addition of more zinc oxide or by the use of zinc anodes, by which latter process spelter can be converted into zinc dust.

NOTES FROM THE U. S. BUREAU OF STANDARDS*

THE FAILURE OF BRASS.—1. MICROSTRUCTURE AND INITIAL STRESS IN WROUGHT BRASSES OF THE TYPE 60 PER CENT. COPPER, AND 40 PER CENT. ZINC.[1]

By P. D. Merica and R. W. Woodward.

[ABSTRACT.]

An investigation has been made of the causes of failure of a number of articles, particularly bolts, of wrought brass of the type 60 : 40, *i.e.*, such as naval brass, manganese bronze, etc., with particular reference to the microstructure of the material and the presence in it of initial stress. In the course of this investigation, the physical properties, microstructure, and initial stress distribution have been studied in some 250 materials, some of which had been in service in the Catskill Aqueduct construction, in the Filtration Plant of the City of Minneapolis, in the U. S. Navy Department, and in the Panama Canal construction, and some of which was new material, rods, having been kindly furnished by several manufacturers.

Measurement of initial stress was made largely by the Heyn method, other methods for approximate and rapid determination of such stresses are discussed and tested. A convenient and readily measurable initial stress "characteristic" value is that of the average stress without regard to sign. The initial stresses in brass rods and bolts tested varied greatly both in distribution and magnitude, average stresses from 1000 to 30,000 lbs./sq. in., fiber stresses of from 0 to 80,000 lbs./sq. in. were found; in extruded and forged rods compressional stress is found in the outside layers, in drawn rods on the other hand, the outside layers are in tension.

Some physical properties, the chemical analysis, and initial stress values of some typical materials tested are given in the following table:

* Communicated by the Director.

[1] Technologic Paper No. 82.

Physical Properties.

B. S. No.	Material.	Chemical Analysis. Copper.	Zinc.	Tin.	Iron.	Tensile Strength. Ultimate strength lbs., sq. in.	Proportional limit, lbs., sq. in.	Elongation in 2 in., per cent.	Initial Stress. Average stress, lbs., sq. in.	Maximum fiber stress, lbs., sq. in.	Stress in outer layer.[2]
3	Manganese bronze....	60.0	38.6	0.78	0.5	70 000	17 000	33	25 000	44 000	T
85	Naval brass.....	59.8	39.3	0.61	....	61 000	16 000	46	2 000	7 000	T
136	Manganese bronze....	59.1	39.3	0.78	0.70	72 000	27 500	44	22 000	34 000	T
160	Manganese bronze....	57.3	40.7	0.94	1.08	61 000	14 000	28[1]	30 000	84 000	T
172	Muntz Metal.....	59.4	40.2	....	0.02	64 000	36 000	40	4 000	8 000	C
174	Manganese bronze....	56.9	40.1	1.63	1.18	84 000	36 000	22	4 000	9 000	C
187	Naval brass.....	60.0	39.6	0.40	....	64 600	28 700	33	6 000	14 000	C
189	Manganese bronze....	56.6	40.8	1.00	1.50	61 600	24 000	..	8 000	12 000	C
205	Manganese bronze....	58.8	39.6	0.39	1.06	84 600	52 000	22	5 000	9 000	T

[1] Elongation over 3 in.
[2] C = compression; T = tension.

Materials 85, 136, 172, 174, and 205 were new, Nos. 3 and 160 had season-cracked in service, and Nos. 187 and 189 had been in service under moderate stress for months without showing signs of failure.

Failures by fracture or fissure have occurred in these materials,

(1) as a result of the presence of initial stresses of large values,

(2) as a result of service over-stress due for example to the drawing up of bolts too tightly, and

(3) as a result of improper and faulty practice in forging bolt heads, flanging plates, etc.

An average initial stress value of 500 lbs./sq. in. is to be regarded as a safe stress limit for rods and bolts of usual size; under normal service conditions, in which the service stresses are themselves not greater than from 5000 to 10,000 lbs./sq. in. Where the initial stress value or the sum of initial stress in tension and the tensional service stress approach the elastic limit of the material the material is likely to fail.

It was shown that the initial stresses in rods could be relieved by annealing for one or two hours at low temperatures, 300°C to 400°C, at which the physical properties were not appreciably affected.

DURABILITY OF STUCCO AND PLASTER CONSTRUCTION.*

By R. J. Wig, J. C. Pearson, and W. E. Emley.

[ABSTRACT.]

OWING largely to its general attractiveness the so-called "stucco house" has become very popular in recent years, especially in the suburban districts of large cities. In fact, the increase in the use of stucco for residence construction has been so rapid that there has been little opportunity to observe whether the methods and materials commonly employed in this class of construction will stand the test of time and insure satisfactory service and durability. In consequence many inquiries are received by the Bureau on this subject, a considerable number of them being prompted by the knowledge of failures or of cases in which stucco has not proven satisfactory.

* Technologic Paper No. 70.

Five years ago (in 1911) the Bureau in co-operation with the Associated Metal Lath Manufacturers undertook to carry out some exposure tests of metal lath plastered with various plastering materials for the purpose of determining the durability of different types of lath and the best methods of construction to insure the protection of the metal from corrosion. These tests (which are still in progress) have demonstrated that painted or preferably galvanized lath well embedded in a dense, water resistant stucco should preserve the metal indefinitely under normal conditions of exposure.

Not all of the plastering materials used in these tests were satisfactory, and it was the desire of certain manufacturers to have the tests repeated or extended with certain modifications in the mixtures and methods of application. In the meanwhile information was accumulating which indicated that corrosion of the metal lath was not by any means the only fault to be overcome in stucco construction, and suggested that an investigation of the entire subject would be of value to architects and contractors as well as to prospective home owners.

The natural interest of the manufacturers of cement, lime, gypsum, metal lath, hollow tile and many proprietary materials in this subject suggested the desirability of calling a conference and planning further work in co-operation with an advisory committee composed of members of the industrial organizations concerned, together with representatives of the Bureau. This committee was organized in 1914 and its membership now includes representatives from the Supervising Architect's Office of the Treasury Department, the American Concrete Institute, and three contracting plasterers of wide experience from as many large cities as well as representatives from the industries.

This committee by frequent conference and correspondence drew up a program for a comprehensive investigation of stucco construction to be followed later by an investigation of interior plaster construction. In 1915 the plans of the committee materialized in the erection of a test structure on the Bureau grounds containing 56 experimental stucco panels, each approximately 15 feet long and 10 feet high. The building itself is 200 feet long, 26 feet wide, and 24 feet high, the interior being available for the erection of plaster walls and partitions of various types. The stucco panels, which were completed in November, 1915, rep-

resent practically all the common types of stucco construction, a variety of mixtures being used on metal lath, wood lath, hollow tile, brick, concrete block, plaster board, gypsum block and concrete bases.

In April, 1916, a careful inspection of the condition of the panels was made and a progress report drawn up for publication together with a full description of the test structure. This report shows that only two of the 56 panels were entirely free from cracks six months after the panels were erected, and a number of them were in very poor condition. On the other hand about 40 per cent. of the panels were rated as satisfactory, the remainder being in various stages of deterioration. While the condition of the test panels as a whole is rather discouraging, it should be mentioned that the smooth type of finish employed, commercially known as sand float finish, is well adapted to bringing out the small defects, such as cracks, blotches, uneven texture, etc., and since it must be assumed that commercial stuccos are subject to these defects in even larger measure than the carefully constructed test panels, the advisability of using the rougher finishes is apparent.

Up to the present time the investigation has shown the necessity for further experimental work and no attempt will be made to draw up even tentative specifications until the results of this work can be compared and combined with the results of an extensive field investigation. In the latter an endeavor will be made to inspect the condition of stucco houses or buildings which have been standing preferably five years or longer, in order that reliable data may be obtained on the durability of different types of stucco on different bases in different parts of the country.

The present progress report does not, therefore, include definite recommendations for stucco construction, in accordance with the decision of the advisory committee that the tests have not gone far enough to warrant general conclusions. Nevertheless a study of the forms of construction and the present condition of the panels, which are fully described in the report, will yield much suggestive information to those who are especially interested in the subject.

SPECIFICATIONS AND TOLERANCES FOR WEIGHTS AND MEASURES AND WEIGHING AND MEASURING DEVICES.*

[ABSTRACT.]

SPECIFICATIONS and tolerances for weights and measures and weighing and measuring devices were first adopted at tne National Conference on the Weights and Measures of the United States, held at the Bureau of Standards in May, 1913. These specifications and tolerances are designed for the use of inspectors of weights and measures in the tests made in the course of their official inspections. The purpose of the application of them is to eliminate from use weights and measures and weighing and measuring devices that are false, without prejudice to such apparatus as conforms as closely as is mechanically possible, to the official standards; or those which are of such construction that they are faulty, are not reasonably permanent in their indication or adjustment, or are designed to or may be used to facilitate the perpetration of fraud.

Since the original action of the Conference these specifications and tolerances have been adopted as official and put into force and effect in a number of States and cities by the officials of the States and cities concerned, and it has been demonstrated that they can be enforced without hardship and that their enforcement will do much toward eliminating false and fraudulent devices from commercial use. In this way the work of the State and city departments is facilitated and the consumer receives a greater protection from the weights and measures laws.

In order to obtain the greatest measure of efficiency from weights and measures laws and rules and regulations, it is very necessary that uniformity between the various jurisdictions be obtained. By the issuance of these specifications and tolerances there has already been secured a very desirable gain toward this end, and the outlook for a still greater measure of uniformity, through the action of additional States and cities, is very promising.

Since the first adoption of these specifications and tolerances additions and amendments have been made by the Conference from time to time, as opportunity was afforded to study and draft requirements for new types of apparatus coming within

* Circular No. 61.

the purview of the work of the weights and measures official, or as experience gained in the field had demonstrated that some changes were advisable. The experience of several years has now demonstrated that there has been secured a set of requirements which meet the needs of trade throughout the country.

The Bureau of Standards has been represented on the committee appointed by the Conference and the specifications and tolerances have the thorough and complete endorsement of the Bureau, which joins with the Conference in recommending the adoption of these specifications and tolerances by the States.

SPECIFICATIONS FOR AND METHODS OF TESTING SOAPS.*

[ABSTRACT.]

A GENERAL discussion of soap, including its definition, a brief description of the materials entering into its manufacture and the theory of saponification is followed by the enumeration of the chief varieties of soap and the requirements in each case. Recommended specifications are given for milled toilet, white floating, liquid, salt-water, two grades of laundry, and chip soaps which have been prepared after careful consideration of the opinions of both users and manufacturers. To this is added a section on the methods of sampling cake, liquid and chip soaps, the preparation of the samples in the laboratory and methods of analysis. The methods of analysis include the determination of volatile matter, free alkali or acid, alkali as carbonate, borate and silicate, sulphate of the alkali, matter insoluble in water, unsaponified matter, total fatty acids, titer test and neutralization values of the fatty acids, rosin, total alkali, chloride, anhydrous soap and qualitative tests for rosin and sugar.

* Circular No. 62.

How Oil Burners Help Boilers Over Peak Loads. ANON. (*Electrical World*, vol. lxviii, No. 16, October 14, 1916.)—By rearranging one of its boiler batteries into a front-and-rear-fired boiler, and by installing different systems of oil burners under other boilers, with provision for quickly changing back to coal firing in an emergency, the St. Joseph (Mo.) Railway, Heat, Light and Power Company has insured itself against possible operating difficulties due to shortage of either oil or coal. In addition, the efficiency of the boilers and of the station as a whole has been increased by the use of oil by making it possible to keep a minimum number of boilers in operation.

The overload rating of one of the boiler batteries was increased from 120 per cent of full load rating to 250 per cent by making simple alterations in the boiler interior and installing oil burners at the rear. Under normal load, this battery is operated at about 120 per cent full load rating, using only the chain grate stokers. During peak load, the additional capacity is secured by turning on the oil burners at the rear instead of firing additional boilers. With one battery firing coal only and another firing coal in the front and oil in the rear, and still another in which the oil fixtures can be quickly removed and the stokers already in place put in service, a scarcity of oil can cause no serious operating trouble. With one battery firing oil only and another firing oil above the grates, and still another firing oil from the rear, a scarcity of coal may be readily coped with. In normal operation the coal-fired boilers are worked under practically constant fire, and the fluctation in load is taken care of almost entirely with the oil-fired boilers which lend themselves readily to control.

Galalith in Germany. H. H. MORGAN. (*U. S. Commerce Reports*, No. 238, October 10, 1916.) Under the name "galalith," a bone-like substance similar in many respects to celluloid, has been on the German market for some time. Galalith is manufactured from casein by means of formaldehyde. A solution of casein is obtained by treating skimmed milk with caustic alkali. The solution is clarified and the casein precipitated by means of acids and then filtered. The water is then partly extracted by pressure and the product dried very slowly. The drying process extends over a period of several weeks. The casein plates thus obtained are thoroughly saturated with formaldehyde and dried again. The product is somewhat transparent, of a yellowish-white color, and very similar to horn.

Galalith is an excellent insulating material, and may be utilized either in the cold state or after it has been softened by using hot water. It is free from odor and is not so inflammable as celluloid, but is never entirely transparent, and it is not possible to manufacture it in very thin sheets. Its specific weight is 1.317 to 1.35; the hardness is 2.5 according to the Mohs scale. The largest manufacturer of galalith in Germany is the Internationale Galalith Gesellschaft at Hamburg.

NOTES FROM THE PHYSICAL LABORATORY OF THE UNITED GAS IMPROVEMENT COMPANY.*

VARIATION OF THE WAVE-LENGTH SENSIBILITY OF PHOTOELECTRIC CELLS WITH TIME.

By Herbert E. Ives.

In order to use the photoelectric cell in photometry it is essential that the cell have two qualities. First, the relationship between illumination and current should be rectilinear; second, the wave-length sensibility curve must be of permanent character, and for reasons of practicability it should be the same from one cell to another, in order that any means for screening to copy the wave-length sensibility curve of the eye would not have to be worked out separately for each cell.

An investigation of the first point by the writer established the fact that photoelectric cells as previously made for photometric purposes could not be relied on to give the rectilinear relationship. Further study developed the explanation for this, and led to the design of a type of cell in which the current is strictly proportional to illumination. A simultaneous study of the wave-length sensibility characteristics of a number of cells showed these to be widely variant. The present work is part of an investigation being carried on to develop if possible cells of uniform and permanent characteristics, the question of *permanency* being first under study.

The particular cell studied has potassium for the active metal, which is deposited on the inner walls of a three-inch diameter bulb, leaving only a small spot clear for the entrance of the light. The potassium was colored by a hydrogen glow discharge, and the bulb afterward filled with helium gas at a pressure to give the maximum photoelectric current under working conditions.

Measurements of the wave-length sensibility curve have been made at intervals over a period of eight months, during part of which time the cell has stood unused, part of the time it has been used for routine spectrophotometric measurements, and twice it has been exposed for an extended period to a considerable illumination with voltage applied so that a photoelectric current passed continuously.

The result of this test is to show a gradual change in the shape of the wave-length sensibility curve, corresponding to either an increase of red or a decrease of blue sensitiveness, probably the

* Communicated by the Chief Physicist.

latter. The relative blue and red sensitiveness has changed in the period mentioned by roughly forty per cent. Time, rather than the amount of exposure of the cell, appears to be the determining factor. A slow diffusion of the sensitizing hydride layer into the pure alkali metal layer beneath is a possible explanation. The experiments will be continued.

HUE DIFFERENCE AND FLICKER PHOTOMETER SPEED.

By Herbert E. Ives.

THE critical speed of the flicker photometer at its equality setting has always been considered and treated by the writer as a function of the hue difference. Critical speeds for the spectrum, compared with a carbon lamp standard, published some years ago, showed a minimum in the yellow, which was ascribed to the hue distance between the yellow carbon lamp and spectrum at that point being smaller than at any other point. Recently Troland has obtained similar curves which he interprets as being reciprocals of the luminosity curve, on the ground that the low critical speed means greater *whiteness*, which he identifies with brightness.

In the paper of which this is an abstract the exact relationship between speed and hue difference is worked out on the basis of the theory recently developed and confirmed by experiment. It follows from this theory that the minimum critical speed in comparing the spectrum against any colored light occurs at the wavelength which is distant from the spectrum the least number of hue steps. If the comparison lamp is red, the minimum speed is in the red, if blue, in the blue, if yellow-white, in the yellow, but with a much higher speed at the blue than at the red end, while for a true white (5000° black body) the curve is symmetrical about a minimum in the green. The hue distances were worked out from the color sensation and hue difference data of Koenig and Steindler.

The experimental work was carried through with the new polarization flicker photometer, fitted to a constant deviation spectrometer. Curves of the predicted type were found in each case. Since the luminosity curve remains fixed, no matter what the color of the comparison lamp, these speed curves, with their minima occurring at any point one desires in the spectrum, show the "reciprocal of the visibility curve" idea erroneous.

THE FRANKLIN INSTITUTE

(*Proceedings of the Stated Meeting held Wednesday, November* 15, 1916.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 15, 1916.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 9.

The paper of the evening was presented by Jacques Loeb, M.D., D.Sc., Ph.D., Head of Department of Experimental Biology, Rockefeller Institute, New York, on "The Production of Normal Animals from Unfertilized Eggs by Physico-Chemical Means."

The speaker described the means by which normal larvæ can be produced from unfertilized eggs of marine animals and called attention to the conclusions which can be drawn from these experiments concerning the mechanism of natural fertilization. The production of normal frogs from unfertilized eggs was next considered as well as the question of their sex. A full explanation of the various stages of fertilization and development was also given.

The subject was illustrated by diagrams, lantern slides and specimens of frogs produced from unfertilized eggs.

After a vote of thanks to the speaker the meeting adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, November* 1, 1916.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 1, 1916.

MR. C. E. BONINE *in the Chair.*

The following reports were presented for first reading:

No. 2668.—Linear Hot-Wire Anemometer.

No. 2677.—"Midget" Marvel Flour Mill.

The following reports were presented for final action:

No. 2675.—Sharples Super-Centrifuge.

Edward Longstreth Medal of Merit to The Sharples Specialty Company, of West Chester, Pa., adopted.

No. 2638.—Herr's Continuous Automatic Centrifugal.

Final action deferred.

No. 2658.—Copes Boiler Feed Regulator. Advisory.

R. B. OWEN,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A stated Meeting of the Section was held in the Hall of the Institute on Thursday, October 26, at 8 o'clock P.M. with Dr. Harry F. Keller in the chair. The minutes of the previous meeting were approved as read. John Johnston, Sc.D., of the Geophysical Laboratory of the Carnegie Institution of Washington, Washington, D. C., read a paper on "Some Effects of High Pressure." The apparatus used for the production, application and measurement of high pressures—pressures as high as 30,000 atmospheres—was described, and certain parts of the apparatus were exhibited. The influence of high pressures on such properties as volume, melting point, and electrical resistance was discussed; and stress was placed upon the fact that temperature and pressure are analogous variables. The communication was discussed, and, on motion of Dr. Walton Clark, a vote of thanks was extended to Dr. Johnston. The meeting then adjourned.

JOSEPH S. HEPBURN,
Secretary.

Section of Physics and Chemistry.—A stated meeting of the Section was held in the Hall of the Institute on Thursday, November 2, 1916, at 8 o'clock P.M. Dr. Gellert Alleman occupied the chair. The minutes of the previous meeting were approved as read.

A. V. Bleininger, B. S. C., Ceramic Chemist, Bureau of Standards, Pittsburgh, Pa., delivered a lecture entitled "The Development of the Ceramic Industries in the United States." The various classes of ceramic raw materials were discussed, and special reference was made to the resources of the United States, and to recent applications of the principles of colloidal chemistry in the purification of kaolin. A description was given of the changes produced by the action of heat on kaolin (dehydration, polymerization, sintering, and fusion), and of the influence exerted by these changes on the porosity, density, and viscosity. The minute structure of pottery was discussed. The manufacture of structural clay products, refractories, stoneware, whiteware, and porcelain received attention; and various forms of machinery used in the industry were described, especial stress being placed on the adaptation of the principle of the tunnel kiln to American conditions.

An interesting discussion followed the lecture; a vote of thanks was extended to the speaker of the evening, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Section of Physics and Chemistry.—A stated meeting of the Section was held on Thursday, November 9, 1916, in the Hall of the Institute at 8 o'clock P.M. Dr. George A. Hoadley occupied the chair.

P. G. Nutting, Ph.D., Director of Research Laboratory, Westinghouse Electric and Manufacturing Company, Pittsburgh, Pa., delivered a lecture entitled "The Fundamental Principles of Good Lighting." Dr. Nutting

stated that criteria for proper lighting rest ultimately with the performance of the eye itself; that is, upon the ease, comfort and precision with which the eye functions. The eye adapts itself to certain lighting conditions with extreme facility, to others with great difficulty or not at all. Data on visual sensibility, efficiency and tolerance were reviewed. From these are deduced the principles governing visually efficient lighting at each of the four lighting levels with which we are concerned. Ideal lighting was described and finally applications to practical lighting were outlined.

After an interesting discussion by Dr. Herbert E. Ives, Mr. Norman Macbeth, and others, a vote of thanks was extended to the speaker of the evening and the meeting adjourned.

T. R. PARRISH,
Acting-Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, November* 8, 1916.)

RESIDENT.

MR. JOHN C. BULLITT, 3D, 222 South Nineteenth St., Philadelphia, Pa.

DR. FARRY R. M. HITCHCOCK, 4038 Walnut St., Philadelphia, Pa.

MR. I. N. KNAPP, Engineer, The United Gas Improvement Company, Broad and Arch Sts., Philadelphia, Pa.

MR. JOHN M. MCCHESNEY, General Manager, Keystone Leather Chemicals Company, and for mail, 150 West Central Ave., Moorestown, N. J.

MR. IRVING B. SMITH, Chief of Research Department, Leeds & Northrup Company, Philadelphia, Pa., and for mail, Ambler, Pa.

MR. HOLLINSHEAD N. TAYLOR, Manufacturer of Tin Plate, 300 Chestnut St., Philadelphia, Pa.

NON-RESIDENT

MR. ARTHUR E. CHILDS, President, Massachusetts Lighting Companies, 77 Franklin St., Boston, Mass.

ASSOCIATE.

MR. CHARLES N. WEYL, Student, 6506 Lincoln Drive, Germantown, Philadelphia, Pa.

CHANGES OF ADDRESS

MR. WILLIAM N. ALLEN, 557 Church Lane, Germantown, Philadelphia, Pa.

MR. IRWIN A. BECKER, 2839 Ellis Ave., care of Michael Reese Hospital, Chicago, Ill.

MR. THOMAS J. DOLAN, Torresdale, Pa.

MR. MITCHELL HARRISON, Nokesville, Va.

DR. CHARLES H. HERTY, 35 East Forty-first St., New York, N. Y.

MR. CARY T. HUTCHINSON, 33 West Thirty-ninth St., New York, N. Y.

MR. E. E. KELLER, 21 Arnold Park, Rochester, N. Y.

DR. WALTER F. RITTMAN, Salem, Ohio.
MR. MELVIN L. SEVERY, The Ratcliffe, 1329 West Fifth St., Los Angeles, Cal.
MR. A. F. SHATTUCK, Hotel Angeles, Los Angeles, Cal.
MR. HORACE B. SMITH, Montgomery Road, Windsor Hills, Baltimore, Md.
PROF. VERNON A. SUYDAM, New Hampshire College, Durham, N. H.
MR. JOHN W. TOWNSEND, Y. M. C. A. Library, 1421 Arch St, Philadelphia, Pa.

NECROLOGY.

Mr. Theodore N. Ely was born at Watertown, N. Y., on June 23, 1846, and died at his home in Bryn Mawr, Pa., on October 28, 1916.

He was educated at the Rensselaer Polytechnic Institute and was graduated in 1866 as a Civil Engineer.

In 1868 Mr. Ely entered the Civil Engineering Department of the Pennsylvania Railroad and during the forty-three years that he was engaged in railroad work he was Assistant Engineer of the Philadelphia and Erie Division, Superintendent of the Middle Division, and Superintendent of the Philadelphia and Erie Division and Assistant General Superintendent of Motive Power of the same Division, and prior to his retirement in 1911 he was Chief of Motive of the Pennsylvania Railroad lines East and West of Pittsburgh.

Mr. Ely was a member of the leading engineering societies of the United States and Great Britain, and was also connected with the important clubs of New York, Philadelphia, and Washington.

He became a member of the Franklin Institute in 1877.

Mr. George W. Spiese, 1642 Green St., Philadelphia, Pa.

LIBRARY NOTES.

PURCHASES

AMERICAN RAILWAY MASTER MECHANICS' ASSOCIATION, The Locomotive Dictionary. 1916.
BREARLEY, HARRY.—Heat Treatment of Tool Steel. 1916.
BUHLMANN, J.—Classic and Renaissance Architecture. No date.
BURTON, E. F.—Physical Properties of Colloidal Solutions. 1916.
Coal Miner's Pocketbook. 1916.
COSGROVE, J. F.—Coal, Its Economical and Smokeless Combustion. 1916.
ECCLES, W. H.—Wireless Telegraphy and Telephony. No date.
FLANDERS, W. F.—Galvanizing and Tinning. 1916.
FLINN, WESTON and BOGART.—Water Works Handbook. 1916.
GOLOVINSKY, M.—New English-Russian and Russian-English Dictionary. No date.
JEANS, J. H.—Dynamical Theory of Gases. 1916.

JOHNSON, BRYAN and TURNEAURE.—Theory and Practice of Modern Framed Structures. 3 vols. 1916.

JUDGE, A. W.—Design of Aeroplanes. 1916.

MEGRAW, H. A.—The Flotation Process. 1916.

MILLER, S. W.—Oxy-acetylene Welding 1916.

Mining World.—Index to Current Literature. Vol. 8. 1916.

GIFTS.

American Society of Civil Engineers, Transactions. Vols. 42 to 62 inclusive, 65 to 69, 71, 73 to 76, inclusive, 1899 to 1913. New York, 1900 to 1914. (From Mr. William R. Webster.)

American Society of Mechanical Engineers, Transactions. Vol. 37, 1915. New York, 1916. (From Mr. William R. Webster.)

American Steel and Wire Company, Manual of Process of Water Purification. Chicago, 1916. (From the Company.)

Argentine National Commission, The Argentine Republic, Panama-Pacific Exposition, 1915. San Francisco, 1915. (From the Commission, through the U. S. Bureau of Education.)

Atchison, Topeka & Santa Fe Railway Company, Twenty-first Annual Report, 1916. New York, 1916. (From the Company.)

Baltimore and Ohio Railroad Company, Seventy-eighth to Eighty-eighth Annual Reports, 1904–1914. Baltimore, 1904–1914. (From Robert D. Jenks, Esq.)

Boston and Maine Railroad, Eightieth Annual Report, 1913. Boston, 1913. (From Robert D. Jenks, Esq.)

Boston and Maine Railroad, Eighty-third Annual Report, 1916. Boston, 1916. (From the Company.)

Boston Elevated Railway Company, Nineteenth Annual Report, 1916. Boston, 1916. (From the Company.)

Brown and Sharpe Manufacturing Company, Catalogue No. 27, Small Tools. Providence, R. I., 1916. (From the Company.)

Buckeye Engine Company, Catalogue of Power Presses. Salem, Ohio, 1916. (From the Company.)

Canada, Minister of Public Works, Report on the Ottawa River Storage, 1915. Ottawa, 1916. (From the Minister.)

Canadian Pacific Railway Company, Report of the Proceedings, Thirty-fifth Annual Meeting, 1916. Montreal, 1916. (From the Company.)

Central Railroad of New Jersey, Reports 1908, 1909, and 1910. New York, 1908–1910. (From Robert D. Jenks, Esq.)

Chesapeake and Ohio Railway Company, Thirty-second to Thirty-seventh Annual Reports, 1910–1915. Richmond, Va. 1910–1915. (From Robert D. Jenks, Esq.)

Chicago and North Western Railway Company, Fifty-second to Fifty-sixth Annual Reports, 1911–1915. Chicago, 1911–1915. (From Robert D. Jenks, Esq.)

Chicago, Burlington and Quincy Railroad Company, Sixty-second Annual Report, 1916. Chicago, 1916. (From the Company.)

Chicago, Milwaukee and St. Paul Railway Company, Forty-seventh Annual Report, 1911. Chicago, 1911. (From Robert D. Jenks, Esq.)

Chicago, Rock Island and Pacific Railway Company, Thirty-sixth Annual Report, 1916. Chicago, 1916. (From the Company.)

Cleveland, Cincinnati, Chicago, and St. Paul Railway Company, Twenty-second Annual Report, 1910. Cincinnati, 1910. (From Robert D. Jenks, Esq.)

Columbia University, Catalogue, 1915–1916. New York, 1916. (From the University.)

Connecticut Agricultural Experiment Station, Thirty-ninth Annual Report, 1915. Hartford, 1916. (From the Station.)

Delaware and Hudson Company, Eighty-first Annual Report, 1910. New York, 1910. (From Robert D. Jenks, Esq.)

Finland, Meddelanden från Industristyrelsen I Finland, Sextifemte Häftet, 1916, and Suomen Teollisuushallituksen Tiedonantoja, Kuudeskymmenesviides Vihko, 1916. Helsingfors, 1916. (From the Industristyrelsen.)

Florida East Coast Railway Company, Annual Report, June 30, 1916. New York, 1916. (From the Company.)

Great Northern Railway Company, Twenty-seventh Annual Report, 1916. St. Paul, Minn., 1916. (From the Company.)

Greenfield Tap and Die Corporation, Catalogue No. 37, Gages, Taps, Dies. Greenfield, Mass., 1916. (From the Company.)

Haverhill, Massachusetts, City Engineer, Annual Report, 1915. Haverhill, 1916. (From the City Engineer.)

Hill Brunner Foundry Supply Company, Catalogue No. 10, Foundry Facings, Supplies and Equipments. Cincinnati, Ohio, 1916. (From the Company.)

Institution of Naval Architects, Transactions, Vol. lviii, 1916. London, 1916. (From the Institution.)

Lake Mohonk Conference on International Arbitration, Report of the Twenty-second Annual Conference, 1916. Mohonk Lake, N. Y., 1916. (From the Conference.)

Lake Shore and Michigan Southern Railway Company, Thirty-ninth, Fortieth, Forty-first, Forty-fourth, and Forty-fifth Annual Reports, 1908–1914. Cleveland, 1908–1914. (From Robert D. Jenks, Esq.)

Lincoln Electric Company, Catalogue of Lincoln Motors. Cleveland, no date. (From the Company.)

Lincoln Memorial University, Catalogue, 1916, and Announcements, 1917. Harrogate, Tenn., 1916. (From the University.)

Louisville and Nashville Railroad Company, Sixty-fifth Annual Report, 1915–1916. Louisville, Ky., 1916. (From Robert D. Jenks, Esq.)

Michigan Central Railroad Company, Sixty-third to Sixty-fifth Annual Reports, 1908–1910. Detroit, 1908–1910. (From Robert D. Jenks, Esq.)

Michigan College of Mines, Year Book, 1915–1916, Announcement of Courses, 1916–1917. Houghton, 1916. (From the College.)

Missouri Botanical Garden, Annals, September, 1916. St. Louis, 1916. (From the Garden.)

New York Board of Water Supply, Tenth Annual Report, 1915. New York, 1915. (From the Board.)

New York Central Railroad Company, Report of the Board of Directors to the Stockholders, 1915. New York, 1915. (From Robert D. Jenks, Esq.)

New York, New Haven and Hartford Railroad Company, Remarks of President Charles S. Mellen, at the Annual Meeting of Stockholders, October 25, 1911; and General Statements for the Forty-first, Forty-second, Forty-third, and Forty-fifth Years, 1912-1916. New Haven, 1911–1916. (From Robert D. Jenks, Esq.)

New Zealand Government Statistician, Statistics of the Dominion, 1915, Vol. II; Trade and Shipping. Wellington, 1916. (From the Government Statistician.)

Norfolk and Western Railway Company, Eleventh to Eighteenth Annual Reports, 1907–1914. Philadelphia, 1907–1914. (From Robert D. Jenks, Esq.)

Northern Central Railway Company, Fifty-seventh, Fifty-eighth, and Fifty-ninth Annual Reports, 1911–1913. Philadelphia, 1912–1914. (From Robert D. Jenks, Esq.)

North of England Institute of Mining and Mechanical Engineers, Annual Report, 1915–1916. Newcastle-upon-Tyne, 1916. (From the Institute.)

Philadelphia Gear Works, Catalogue, 1916. Philadelphia, 1916. (From the Company.)

Philippine Islands, Department of Public Instruction, Bureau of Education, Sixteenth Annual Report of the Director. Manila, 1916. (From the Department.)

Pratt and Whitney Company, Catalogue No. 9. Small Tools. Hartford, Conn., 1916. (From the Company.)

Rensselaer Polytechnic Institute, Catalogue, 1916. Troy, N. Y., 1916. (From the Institute.)

Royal Institution of Great Britain, The Register of the Members, 1916. London, 1916. (From the Institution.)

Rutland Railroad Company, Fortieth to Forty-fourth Annual Reports, 1906–1910. Rutland, Vermont, 1906–1910. (From Robert D. Jenks, Esq.)

Scaife, Wm. B. & Sons Company, Scaife Scientific Water Purification for all Purposes. Pittsburgh, Pa., 1916. (From the Company.)

Southern Pacific Company, Twenty-third to Twenty-seventh Annual Reports, Twenty-ninth, Thirtieth, Thirty-first, and Thirty-second Annual Reports, 1907–1916. New York, 1907–1916. (From Robert D. Jenks, Esq.)

Southern Railway Company, Twenty-second Annual Report, 1916. Richmond, Va., 1916. (From the Company.)

St. Louis and San Francisco Railroad Company, Twentieth Annual Report, 1916. St. Louis, Mo., 1916. (From the Company.)

Stevens Institute of Technology, Annual Catalogue, 1916–1917. Castle Point, Hoboken, N. J., 1916. (From the Institute.)

Sturtevant, B. F. Company, Bulletins Nos. 226 and 228; Catalogue No. 230. Hyde Park, Massachusetts, 1916. (From the Company.)

Swedish Gage Company, Inc., The Limit System. New York, 1916. (From the Company.)

Tennessee Railway Light and Power Company, Report to the Stockholders, 1915. Philadelphia, 1916. (From Robert D. Jenks, Esq.)

Thompson & Company, Pty., Ltd., Catalogues, Dredging for Gold and Tin, 4th edition, and Manufacture of Modern Machinery in Australia. Castlemaine, Victoria, Australia, no dates. (From the Company.)

Union Pacific Railroad Company, Sixteenth to Eighteenth Annual Reports, 1913–1915. New York, 1913–1915. (From Robert D. Jenks, Esq.)

U. S. Bureau of Census, Thirteenth Census of the United States, 1910. Vol. I, Population, Vol. III, Population, Vol. V. Agriculture, Vol. VI, Agriculture, Vol. VII, Agriculture, Vol. IX, Manufactures, Vol. X, Manufactures. Washington, 1912–1914. (From the Bureau.)

U. S. War Department, Office of the Chief Signal Officer, Equipment for Aero Units of the Aviation Sections (Signal Corps), Tentative, 1916. Washington, 1916. (From the Aero Division, War Department.)

Vermont Society of Engineers, Proceedings, 1916. Montpelier, 1916. (From the Society.)

Waltham Grinding Wheel Company, Catalogue No. 16, Waltham Grinding Wheels, Waltham, Mass., 1916. (From the Company.)

West Jersey and Seashore Railroad Company, Fifteenth and Sixteenth Annual Reports, 1910 and 1911. Philadelphia, 1911–1912. (From Robert D. Jenks, Esq.)

Wisconsin Railroad Commission, Reports, Vols. 6 and 7, November 11, 1910, to September 23, 1911. Madison, 1912. (From Robert D. Jenks, Esq.)

BOOK NOTICES.

DISEASES OF OCCUPATION AND VOCATIONAL HYGIENE. Edited by George M. Kober, M.D., LL.D., Professor of Hygiene, Georgetown University, Washington, D. C., President of the Section on Hygiene of Occupations, XV International Congress on Hygiene and Demography, Chairman of the Section on Industrial Hygiene of the American Public Health Association (1915), Secretary of the Association of American Physicians, and William C. Hanson, M.D., formerly with the Massachusetts State Board of Health, Pp. 918, 42 figures. Philadelphia: P. Blakiston's Son and Co., 1916.

Great Britain, France, Germany, Switzerland, and Bulgaria have incorporated into their laws the principle of compensation for occupational accidents and diseases. The United States Government and 33 of the states have during the last few years applied the idea to accidents, but as yet only Massachusetts and California recognize occupational diseases as compensable. An active campaign is now, however, being waged for these measures widely in this country. This is forcing employers, employes, legislators, and the American public generally, as well as physicians, to seek accurate data regarding occupational hazards, their mode of operation and final effects, and efficient means of preventing them. Much has been contributed to the literature of the subject by continental Europe and England, but until recent years comparatively little has been published in the United States. What has appeared in this country has been largely in the form of monographs from individual investigators and government reports.

Kober and Hanson's book is an attempt to summarize and co-ordinate the results of these recent investigations in such a way as to make them available

for reference and at the same time to supply the medical profession with an authoritative text book upon the recognized occupational diseases.

The first part is written primarily for the physician and is a systematic presentation by twenty-two specialists of the specific and systemic diseases of occupation. The second part is contributed largely by Dr. Kober himself and treats of the causes of occupational diseases and of the means of preventing them. The hazards of the various occupational processes are detailed and measures suggested by which they may be minimized or eliminated. In the final portion of the book the contributions are from men whose interests lie in the relation of hospital and medical school work, statistics, government study, and legislation to occupational diseases.

The book is a valuable asset to industrial medical literature. The eminence of its collaborators, such as Emery R. Hayhurst, Frederick L. Hoffman, Alice Hamilton, Luigi Devoto (professor and director of the Milan Clinic for Occupational Diseases), Frederick S. Lee, Thomas M. Legge, Sir Thomas Oliver, Ludwig Teleky, as well as the senior editor, is an indication of its authoritativeness and its classic character. Its range of subjects and the exhaustive references to the original sources at the end of each chapter make it invaluable as a reference work. While not the first American treatise upon the subject, it is the most comprehensive.

T. GRIER MILLER, M.D.

PUBLICATIONS RECEIVED.

Organic Chemistry for the Laboratory, by W. A. Noyes, Ph.D., professor of chemistry in University of Illinois, Urbana, Ill. Third edition, revised and enlarged. 292 pages, illustrations, 8vo. Easton, Pa., Chemical Publishing Co., 1916. Price, $2.00.

U. S. Department of Commerce. Centennial celebration of the United States Coast and Geodetic Survey, April 5 and 6, 1916. 196 pages, illustrations, plates, quarto. Washington, Government Printing Office, 1916.

How to Make Low-pressure Transformers. Third edition with additions by Prof. F. E. Austin, Hanover, N. H. Author, 1916. Price, 40 cents.

U. S. Bureau of the Census: Sam L. Rogers, Director. Mortality statistics, 1914. Fifteenth annual report, 714 pages, maps, tables, diagrams, quarto. Washington, Government Printing Office, 1916.

How to Build up Furnace Efficiency. A hand-book of full economy (including a few notes about industrial efficiency and other things), by Jos. W. Hays, combustion engineer. Tenth edition, revised and enlarged. 158 pages, illustrations, 12mo. Chicago, Author, 1916. Price, $1.00.

Canada Department of Mines, Mines Branch. An investigation of the coals of Canada with reference to their economic qualities as conducted at McGill University, Montreal, under the authority of the Dominion of Canada. Extra volume supplementing report No. 83. Weathering of Coal, by J. B. Porter, E.M., Ph.D., D.Sc. 194 pages, illustrations, diagrams, tables, 8vo. Ottawa, Government Printing Bureau, 1915.

Rodney Hunt Machine Company. Hunt water controlling apparatus.

Catalogue No. 30. 112 pages, illustrations, 8vo. Orange, Mass., Rodney Hunt Machine Co., 1916.

U. S. Bureau of Mines: Bulletin 108. Melting aluminum chips by H. W. Gillett and G. M. James. 88 pages, 8vo. Washington, Government Printing Office, 1916.

U. S. Department of Agriculture: Bulletin No. 393. Economic surveys of county highway improvement. A compilation and analysis of data in eight selected counties, showing comparative financial burdens and economic benefits resulting from highway improvement during a period of years by J. E. Pennybacker, chief of road economics, and M. O. Eldridge, assistant in road economics. 86 pages, plates, 8vo. Washington, Government Printing Office, 1916.

Catalyzer Poisons in the Hydrogenation of Fatty Oils. C. ELLIS and A. A. WELLS. (*Journal of Industrial and Engineering Chemistry*, vol. viii, No. 10, October, 1916.)—One of the main difficulties in the hydrogenation, by the aid of nickel catalyzer, of many low-grade oils, such as some of the fish and whale oils, is that the life of the catalyzer is very short. The fact that in some cases a catalyzer does not last indefinitely and that its life is prolonged in proportion to the purity of the oil indicates that there are present in some fatty oils certain substances which unfavorably affect the catalyzer acting as poison thereto, and sooner or later causing the catalytic agent to become inactive. It has been observed that some kinds or grades of oil may be hydrogenated to an incomplete degree but that they cannot be carried beyond this point, no matter how long the treatment is continued, without change of catalyzer. If to these semi-hardened oils a fresh quantity of catalyzer is added, the hardening will usually proceed to complete saturation. In some cases, a fresh quantity of oil may be treated with seemingly spent catalyzer, when partial hardening will occur. An additional quantity of catalyzer will sometimes carry the oil so treated to completion, showing that the substance which affects the catalyzer is apparently taken up by it under these circumstances, thus leaving the oil in a condition to be readily hardened. Some oils which cannot be readily hardened without a preliminary purifying treatment, may first be agitated with a spent catalyzer, the catalyzer removed, and the oil then incorporated with a fresh quantity of catalyzer when hardening readily occurs.

Experiments with several detoxicating agents added to the oil indicate the effectiveness of copper hydrate. The oil, first having been filtered to remove the resulting copper compound, readily hardened. The copper hydrate used to detoxicate cod and other oils was examined to determine what bodies were taken up from the oils by the treatment. Sulphates were found but no evidence of the presence of phosphates or chlorides was obtained. A blank test on the original copper hydrate showed no sulfates or sulfur present, indicating that sulfur compounds are removed from fatty oils containing them by treatment with copper hydrate.

CURRENT TOPICS.

Origin of "Petrified Forest." ANON. (United States Geological Survey Press Bulletin, No. 286, September, 1916.)—The "Petrified Forest" of Arizona, really a series of petrified forests, lies a short distance south of Adamana, on the line of the Santa Fé Railway. There are four "forests," included in a government reservation called "Petrified Forest National Monument," created by presidential proclamation in 1906. The name "forest" is not strictly appropriate, for the petrified tree trunks are all prostrate and are broken into sections. The logs are the remains of giant trees that grew in Triassic time, the age of reptiles. The trees were of several kinds, but most of them were related to the Norfolk Island pine, now used for indoor decoration. Doubtless they in a near-by region and, after falling, drifted down a watercourse and lodged in some eddy or a sand bank. Later they were buried by sand and clay, finally to a depth of several thousand feet. The conversion to stone was effected by gradual replacement of the woody material by silica in the form called chalcedony, deposited by underground water. A small amount of iron oxides deposited at the same time has given the brilliant and beautiful brown, yellow, and red tints which appear in much of the material.

Some of the tree trunks are 6 feet in diameter and more than 100 feet in length. In the first forest there is a fine trunk that forms a natural bridge over a small ravine, the water having first washed away the overlying clay and sand and then, following a crevice, worked out the channel underneath. The length of this log is 110 feet, and the diameter 4 feet at the butt and 1½ feet at the top.

The petrified woods are beautiful objects to study. When thin slices are carefully ground down to a thickness of 0.003 inch or less and placed under the microscope they show perfectly the original wood structure, all the cells being distinct, though now they are replaced by chalcedony. By studying the sections F. H. Knowlton, of the United States Geological Survey, Department of the Interior, has found that most of these araucarian trees were of the species *Araucarioxylon arizonicum*, a tree now extinct. It is known to have lived at the same geological time also in the east-central part of the United States, where the remains of some of its associates have also been found. These included other cone-bearing trees, tree ferns, cycads, and other gigantic horsetails, which indicate that at that time, the rainfall was abundant.

The Protection of Iron by Electroplating. O. P. WATTS and P. L. DE VERTER. (*Proceedings of the American Electrochemical*

Society, September 28–30, 1916.)—Although nickel-plated iron is satisfactory for use indoors, when exposed to the weather it almost invariably rusts. Brass-plated steel is extensively employed for the cheaper grades of builder's hardware, but it is even more unsatisfactory than nickel-plate for out-of-door use. An electro-deposit of zinc on steel or iron is the only one that will withstand the atmospheric conditions for any reasonable length of time, and a demand is now being made for hardware that has received an electro-deposit of zinc before being plated with any other metal for ornamental purposes, such as nickel, copper, brass or bronze. The double coating gives good service and is the only satisfactory one for hardware which is exposed to the weather.

The superior protective action of electro-galvanizing in comparison with deposits of other metals on iron is well recognized. This has generally been ascribed to the voltaic action; whenever a hole is broken or worn through the plating a voltaic cell is formed between the metal coating and the exposed iron. If the coating consists of a metal which is electro-positive to iron, the latter is cathode and is protected from corrosion, but if the coating is electro-negative to iron this becomes anode, and is corroded worse than if the protective coating were entirely absent. Tables of potentials of the metals show that, of the metals that can be satisfactorily plated out of an aqueous solution, only zinc and cadmium are electro-positive to iron. Since cadmium is not used for plating on account of the expense, zinc remains as the only electroplate which can protect iron by voltaic or galvanic action. Theory and practice appear to be in harmony. Galvanic action requires that two unlike conductors be in electric connection with each other and with an electrolyte. So long as the iron is completely covered by the electroplate there is no opportunity for voltaic action, either corrosive or protective, and, so far as rusting of iron is concerned, it is immaterial what metal constitutes the coating. The protection of iron by deposits of zinc and its universal rusting when plated with other metals seems to indicate that electro-deposits of zinc are less porous than those of other metals, or that in the thickness used commercially all electro-deposits are porous, or on exposure soon become so, and thus the superior protection of zinc is due solely to its galvanic action.

The Sharpness of Photographic Negatives for Enlarging. E. CONSTET. (*Revue Generale des Sciences*, vol. 27, No. 6, March 30, 1916.)—There is too widespread error that the want of sharpness in the photographic image from very rapid gelatino-bromide emulsions is caused by the grain of the plate. It is true that if it is a question of enlarging an image 150 times, special emulsions of collodion and albumin must be employed. With these the grain only becomes observable with a magnification of 200 diameters, and at such magnifications it is only with a highly corrected lens and most precise

mounting of the apparatus that a sharp image can be secured. In the usual operations of photographic enlargement, however, a magnification of more than four diameters is seldom required.

In general terms, fast plates produce images with a grain less fine than slow plates. When the emulsion is prepared at as low a temperature as will insure the dissolution of the gelatin, it is quite transparent but very insensitive. As the emulsion is heated to increase its sensitiveness, it is seen to become more and more opaline, and a microscopic examination shows that the bromide of silver flocculates in grains of increasing volume. There is, however, no necessary relationship between the sensibility of the emulsion and the size of the grain, and the majority of manufacturers have succeeded, by processes more or less secret, in preparing rapid emulsions with a relatively fine grain. For example, among the products of the Lumière works, the " sigma " plate has three times the speed of the " blue label " plate, and yet the grain of the former is notably finer and more uniform than that of the latter. The " violet label " plate has seven times the sensitiveness of the blue label plate, nevertheless its grain is comparable in fineness with the sigma plate. The grain of the sigma plate is minute enough to define details one-fortieth of a millimetre, and with an enlargement of four diameters the sharpness of the image will be the order of one-tenth of a millimetre (about 0.004 inch). In practice, a departure from precise definition from two to two and one-half times this value is admissible. It is therefore not in the grain of the emulsion that the cause of poor definition in enlarging must be sought, but in the defects of the optical system and its mounting and to the treatment of the plate in the developing process.

Three Types of Lenses. C. W. PIPER. (*The British Journal of Photography*, vol. lxiii, No. 2937, August 18, 1916.)—The names of lenses are very numerous, but these names by no means represent different types. Broadly speaking, lenses may be divided into three classes—the portrait, rapid rectilinear, anastigmat classes—but, though this classification may seem quite familiar, it is not certain that the essential differences are generally understood. These differences mainly consist in varied degrees of correction, and the points of chief importance to the user are not the particular aberrations that are corrected, but the varying behavior of the three classes at large and small apertures and over large and small fields. It must be recognized that photographic optics has not yet reached such a stage of perfection as to permit the production of a lens that will work equally well at large or small apertures over either large or small areas. In every case there is a certain amount of compromise, and the correction for a large aperture involves the sacrifice of some other quality, as does also the production of good definition over large fields.

Taking the portrait type of lens first, the early specimens were essentially lenses corrected for very large apertures but over very small fields. At full aperture they may produce the most exquisite definition over an area not much bigger than a postage stamp, but give very inferior results over a larger area. Obviously such lenses may be of extreme value for certain work, and astronomers in particular are always glad to come across a fine specimen of the early type of Petzral portrait lens that possesses these qualities, for the central definition excels anything that can be secured with modern photographic lenses. This particular quality is, however, by no means necessary for portraiture; hence in modern types of portrait lenses some of the central definition has been sacrificed for the purpose of getting better definition over a larger area. The alteration is one of degree only, and so the portrait lens is still essentially a lens that will work at a very large aperture, but will cover with good definition only a very small area or angle.

In the next type of lens, more or less accurately designated "rapid rectilinear," the most essential difference is a reduction of aperture and the power of covering a bigger field. While a 6-inch portrait lens will sharply cover only the central part of a quarter-plate, the rapid rectilinear at f/8 should cover the whole sharply to the corners. This represents about the most that can be expected from rapid rectilinear lenses, and, while the lenses of the same or similiar type have been issued with f/6 apertures under various names, they will not cover such large plates. The best of these f/6 lenses form types intermediate between the rapid rectilinear and the portrait type, while the worst are simply rapid rectilinear lenses fitted with an aperture that is too large to permit of good definition anywhere.

Next is the anastigmat type. This is essentially a lens that at large aperture will cover a large area, but, to attain this very useful quality, again sacrifices have to be made, the chief of which usually is the perfection of definition at small aperture. At first sight this seems a serious matter, but a little consideration will show that it is one of small moment so long as large apertures are in use. The small aperture forms only a small portion of the large one, and the imperfectly corrected area of the lens in use with the small aperture plays a very small part in the formation of the image when the large aperture embracing the more perfectly corrected and much larger areas remote from the centre are used. There is also a certain amount of compromise as regards the definition in the area covered. Perfect definition cannot be secured over the whole area, and, as a rule, the best definition will lie at the centre and in a circular zone somewhere between the centre and the margins of the disk covered. The chief virtue of the anastigmat lens is that it will cover a larger area than either the portrait or rapid rectilinear types at a large aperture. If a large aperture is not wanted, the rapid rectilinear will work almost as well, and, in fact, will fulfil most of the requirements of the average photographer. On the other hand, if a very

narrow angle alone is to be covered, a portrait lens will work as well as an anastigmat, and probably at an even larger aperture. The anastigmat is the most universal of the three types, as it will do all that the other two will do, but for a great deal of ordinary work it is by no means essential.

Belt Conveyors. R. TRAUTSCHOLD. (*The Engineering Magazine,* vol. li, No. 5, August, 1916.)—Material supplied in an adequate and continuous stream can be handled more expeditiously by the belt conveyor than by other form of material-handling equipment. For handling loose material a troughed belt is required, and, though the load that can be supported by a foot of belt is not great, the capacity of even a narrow belt is suprisingly high, owing to the speed at which a belt may be run. For instance, under perfect loading conditions, a belt conveyor only 12 inches wide can handle nearly 90 tons of sand per hour, while one 36 inches wide has a capacity of 800 tons per hour when run at a speed of 375 feet per minute.

Considering a specific belt conveyor installation, one handling 85,000 tons of fine coal per year may be taken as typical and well illustrating the economic value of the device. Such a conveyor, 500 feet long, elevating the load 30 feet in its travel, and distributing it to an overhead bunker 100 feet in length, would not be an unusual installation. With power delivered to the conveyor drive costing 2 cents per horse-power, the net operating cost per ton, including all charges, is 1.957 cents with pin-bearing idler and 1.629 cents with roller-bearing equipment.

Resharpening Hack-saw Blades. ANON. (*The Iron Age,* vol. 98, No. 15, October 5, 1916.)—The Wardwell Manufacturing Company of Cleveland, Ohio, has brought out an automatic power hack-saw blade grinding machine which is said to be the first machine of the kind ever placed on the market. The machine is claimed to be extremely simple and a continuous stream of blades can be fed through it at a rate of 65 teeth per minute. This means that 14 to 18 blades, 18 inches in length can be resharpened in an hour. The blades are sorted by the operator into groups of the same width and pitch. Any width or length of blade with teeth up to as fine as 33 per inch can be resharpened, and it is claimed that they may be resharpened six or eight times or more, depending on the material being cut. It is stated that the actual cost of resharpening one blade does not exceed 2 cents, and that it will effect great economies to users of power hack-saw blades who now discard those blades as soon as they become dull.

Filling Acetylene Tanks. ANON. (*Acetylene Journal,* vol. xviii, No. 4, October, 1916.)—It is such a simple matter to use acetylene when the supply is obtained from a Prest-O-Lite tank that

few persons are aware of the involved processes that render such simplicity possible. Perhaps the most important of these is that unless the charging is carried out in the right way, the operation is attended with great danger of explosion. Most writers on the subject have been content to explain that actually only a very small quantity of the gas exists in the tank at any time, this being retained in the free space at the end nearest the valve, while the remainder of the tank is filled with discs of asbestos, or similar material, which is saturated with a liquid (acetone) having the property of dissolving no less than 25 times its own volume of acetylene for each atmosphere of pressure. There is no risk in handling or using such a tank that has been properly charged, for the reason that the volume of gas present is so small as to involve little chance of developing dangerous pressures even with a considerable rise in the temperature. The safety of the system, however, depends entirely upon proper charging. If the gas is not properly purified and dried the absorbent packing may be fouled and clogged, while the liquid may become polluted, the result being that the absorbing properties of the liquid are greatly reduced.

The gas formed in large generators at extremely low pressure, is first washed in "scrubbers" to remove soluble impurities, such as ammonia, after which it passes to one or more dryers to remove the surplus moisture. Then it is treated to remove such foreign compounds as phosphine and sulphuretted hydrogen, again dried and finally cleaned to remove any particles of lime dust. All these operations are performed at low pressure for the very good reason that free acetylene, even when unmixed with air, is subject to decomposition with explosive violence when subjected to pressures exceeding a gauge pressure of 15 pounds per square inch. After purification, the gas is raised to the charging pressure of 250 pounds by means of a "three-stage" compressor that is thoroughly water-cooled and equipped with a circuit breaker and contact gauge. The pressure is thus "stepped up" without permitting the temperature to rise above a safe amount at any time. In charging the cylinders, as well as in raising the gas to the necessary high pressure, the tanks are carefully maintained at a fixed temperature. From 10 to 20 hours are required to complete the operation, in order that the liquid in the tank may absorb in solution its full quota of gas. A check on the amount of gas absorbed is obtained by weighing each of the cylinders before and after charging.

Acid-Resisting Alloys. W. C. CARNELL. *(The Journal of Industrial and Engineering Chemistry*, vol. viii, No. 10, October, 1916.)—A process that is a success in the laboratory will be a success in the factory if conditions are duplicated. Platinum and glass are available in the laboratory, but may be prohibitive in the factory. The branch of the chemical industry that has suffered most

for materials for the construction of apparatus is the mineral acids division. For many years various metals and alloys were offered for which more or less acid-resisting properties were claimed. They had their uses, but as complete acid-resisting materials they were not successful.

The real dawn of an acid-resisting alloy came with the use of "silicon-iron" alloy. In May, 1912, the first silicon iron alloy in the United States was put on the market under the name "Duriron" by the Duriron Castings Company of Dayton, Ohio. In 1913 the American rights for "Tantiron" were acquired by the Bethlehem Foundry and Machine Company, of South Bethlehem, Pa. Both of these alloys are characterized by a content of about 14 per cent of silicon, though the amounts of other components are not identical. They both have a melting point of about 2500° F. and a tensile strength 5 per cent less than cast-iron. Silicon iron alloy as exploited under the above names is very resistant to all strengths of sulfuric acid, and apparatus made of this alloy is used in all forms of concentrating vessels and cooling devices for the concentration of sulfuric acid. Silicon iron alloy castings have extensively replaced stoneware parts for the manufacture of nitric acid. It can be cast into all the different forms required for nitric acid apparatus and is resistant to the acid of various strengths. Castings can be made as readily and quickly as those of cast-iron, though it cannot be cast in rectangular shapes or flat surfaces. Since its introduction, new chemical processes have been started which were impossible before, because of lack of suitable apparatus. Silicon iron alloy is being improved upon rapidly and the time does not seem far distant when all sorts of vessels will be made of this or similar alloy that will give to the chemical industry the ideal non-corrosive material that may be fabricated into all the shapes peculiar to the needs of the industry.

The Small Geared Steam Turbine. ANON. (*Power*, vol. xliv, No. 15, October 10, 1916.)—When Professor De Laval first introduced his simple impulse turbine, he found it necessary to run the turbine at very high speeds to secure good economy. But in order to adapt the turbine to the electric generators of that day, it was found necessary to introduce a reduction gear between the turbine and generator. This method is still used by the builders of the De Laval turbines on small units. The other types of turbines that were introduced at nearly the same time or later, such as the Parsons, the Rateau and the Curtis, were at first designed to run at much more moderate speeds, so that they could be direct connected to electrical machinery or to pumps without the use of intermediate gearing. In a late development of the simple impulse type, the steam is redirected so as to impinge on the blades a number of times and thus permit lower wheel speeds and direct connection.

Quite recently one of the largest turbine builders in this country has developed a new line of simple impulse turbines to be run at speeds of 6000 to 7000 revolutions per minute and to be connected through gears to the machines which they drive. These units have met with a considerable measure of success and are increasing rapidly in popularity. The most important consideration in returning to the geared unit after the development of the slow-speed repeated-flow simple impulse turbine is that of economy. High-speed geared units are said to show a gain of economy of 15 per cent. over the repeated flow type, slower-speed direct connected units.

Some difficulty was experienced with the wearing of the teeth of the earlier gears, but this has been overcome by accurate workmanship and suitable lubrication. The Westinghouse-MacAlpine floating-frame was introduced to insure proper contact and thus avoid cutting. At about the same time, however, gears were used on the large Parsons turbines without special provision for adjustment other than accurately made bearings which were kept well lubricated. This apparently has been all that is necessary, for the newer American types have proved satisfactory without special devices to maintain alignment. The early gears were usually of bronze. High-carbon steel is now used to a great extent and seems better suited to the purpose.

The small geared-turbine provides a cheap light-weight and economical unit. It will not cause any revolution in power plant practice but it will gradually find its place as its advantages and its adaptability to special conditions and particular uses are recognized.

The Wire Drag in Hydrographic Surveying. E. L. JONES. (*U. S. Coast and Geodetic Survey*, Serial No. 47, Elements of Chart Making, 1916.)—Surveying our waters for navigational charts has in the past largely been done by means of sounding with the lead line, and for the reason of the limitations of that method the information as to the form of the bottom so obtained is restricted to points more or less separated. In other words, the hand lead, weighing about 12 pounds, is attached to a line and cast overboard at various intervals to ascertain the depth of water, and does not give a complete and final knowledge of certain water areas. As surveys by the lead-line method failed frequently to reveal even an indication of the presence of rocky pinnacles, ledges, bowlders, coral reefs, etc., it became more and more evident that some new device especially adapted to the requirements of such localities was urgently needed. For this purpose the wire drag was adopted.

From its crude original form there has been rapidly developed, by the Coast and Geodetic Survey, an apparatus which in practice gives results that are final. It consists of a horizontal bottom wire, supported at intervals by adjustable upright cables suspended from buoys on the surface. These uprights can be lengthened or short-

ened for various required depths, and to maintain the bottom wire at a given depth below the surface of the water by making allowance for the rise and fall of the tide. The uprights are maintained in a nearly vertical position by means of weights attached to their lower ends. Intermediate between the uprights, wooden floats are attached directly to the drag wire to prevent sagging between the uprights. The end weights and buoys are larger than the intermediate, and to them the towing gear from the launches is attached.

In operation the drag is extended by directing the course of the launch outward from the middle of the drag as well as forward along the center of the area to be swept. An interesting feature of the apparatus is the signalling system between the end launches, made necessary by the great length of the drag which is sometimes four or five miles long. Upon meeting an obstruction in its course, the drag at once indicates the obstruction and points out its location. As soon as the drag wire touches an obstruction, there is a marked increase in the tension on the drag, which is noted immediately on the spring balance to which the tow line is attached; and the position of the shoal is shown by the buoys which line up between the obstruction and the launches. A buoy is then placed at the intersection of the two lines of drag buoys, the drag is cleared and moved ahead on its course and the detailed examination of the spot is then made by a sounding party in a small tender or sounding boat.

Characteristics of Small Dry Cells. C. F. BURGESS. (*Proceedings of the American Electrochemical Society*, September 30, 1916.)—The flash light industry has been greatly stimulated by the development of the high efficiency miniature tungsten lamps, and of an influence equal in importance is the decided improvement in the qualities of the battery. The two most important characteristics by which the value of flash light batteries may be determined are ability to furnish light over a period of time, or its capacity, and its ability to withstand deterioration when not in use, or its shelf life. Other characteristics of importance are voltage, recuperation, uniformity, size, cost. Since by far the most important use of small cells is for flash light service, the tests aim to parallel as far as practicable this type of service.

The two most important characteristics by which the value of flash light batteries may be determined are its capacity, and its shelf life. The standard method of capacity test which has been used in the laboratories of several manufacturers is to adopt a fixed standard of resistance through which the individual cell is discharged, and noting the length of time on discharge required for the cell to drop to a certain voltage. It has been found that four ohms per cell of battery used is close to the average resistance of the common sizes of standard lamps, and this is adopted as the standard. There is room for argument as to what voltage should be taken as that

at which the battery becomes useless. With the pressure at one-half volt per cell the light is sufficient to read a clock dial but not for general flash light service. Accordingly, 0.5 volt per cell has been taken as the standard limiting value or "end point." It appears to be a general practice among manufacturers to guarantee their batteries against a falling off in open circuit voltage. Many tests and long experience indicate that a far better method of determining the deterioration going on within the cell is measured by the short circuit flash which the cell gives when connected momentarily to the ammeter. While the reading it not strictly proportioned to the ampere-hour capacity, it is nevertheless a far better indication than the dropping of open-circuit voltage.

Small cells are found on the market in a great variety of sizes and forms of battery. The most common form is the two-cell and three-cell tubulars for use in metal and fibre cases. Of almost equal importance is the two-cell and three-cell battery of smaller dimensions, the cells being placed side by side for use in flat cases and commonly designated as the "case type." These cells vary in size from 9/16 to 1¼ inches in diameter and from 1 9/16 to 2¼ inches in length. They have a voltage of 1.45 to 1.55 or even 1.6. Capacity tests show that the best cells have a capacity about 100 per cent. above the poorest, and durability tests show much greater differences. If a manufacturer could discover some method of construction so that each cell would be exactly like the best which he can produce, it would be an important achievement in the improvement of quality.

Brick Roads for Country and City. ANON. (*Professional Bulletin, U. S. Department of Agriculture.*)—Country roads paved with vitrified brick are becoming quite common in many of our States, according to the professional bulletin "Brick Roads," recently issued by the Office of Public Roads and Rural Engineering, U. S. Department of Agriculture.

The purpose of the new bulletin, which can be had free, so long as the Department's supply lasts, by road engineers, supervisors, and others contemplating the construction of brick roads, is to make clear certain important essentials in the choosing of brick for a pavement and in laying it so that the highway will endure. The principal advantages which brick roads possess, according to the authors, may be stated briefly as follows: (1) They are durable under practically all traffic conditions; (2) they afford an easy traction and moderately good foothold for horses; and (3) they are easily maintained and kept clean. The principal disadvantage is the high first cost. The defects which frequently result from lack of uniformity in the quality of brick or from poor construction are usually to be traced indirectly to an effort to reduce the first cost or to a popular feeling that local materials should be used, even when of inferior quality.

The first brick pavement constructed in this country, it is stated, dates back to 1872, and Charleston, W. Va., has the distinction of being the first American city to employ this product for paving. For a number of years after its introduction, however, the use of paving brick was confined principally to city streets, and, owing to the frequent inferiority in the quality of the brick and the lack of care in construction, very few of the early pavements proved satisfactory. Even now, after the experience of forty years has demonstrated that it is entirely practicable to construct satisfactory brick pavements when proper care is exercised, and that much waste results from the use of poor materials or faulty construction, instances can still be frequently found where comparatively new pavements have wholly or partially failed from causes which might easily have been prevented.

The selection of the brick is one of the most essential features, for the success or failure of such pavements depends, to a large extent, on the way in which the brick will withstand the kind of traffic for which the road is designed. The engineers point out that it is very poor economy to use a locally manufactured brick unless this brick is of a high standard. Color, specific gravity, absorptive power, or even the crushing strength, of brick are not necessarily reliable tests. In general, of course, the brick should be uniform in size, perfect in shape, free from ragging and deep kiln-marks. Each brick should be homogeneous in texture and free from objectionable seams. Fire cracks should be limited in number and extent, and the entire brick should be vitrified and should contain neither unfused nor glassy spots. Even field inspection and laboratory analysis, unless conducted by those especially experienced, however, may prove of little value.

According to the bulletin, the test upon which highway engineers appear to place most reliance is the "rattler" or abrasion test. In this test 10 dry bricks are placed in a rattle barrel with 10 cast-iron spheres 3¾ inches in diameter and weighing 7.5 pounds each, and enough spheres 1⅞ inches in diameter and weighing 0.95 pounds each to make up 300 pounds of metal. The loaded rattle barrel is then revolved continuously 1800 times at a speed not lower than 29½ nor exceeding 30½ revolutions per minute. When the test is over the results are reckoned in terms of the loss in weight sustained by the brick. No piece of brick which weighs less than one pound is considered as having withstood the test.

Good paving brick under this test ordinarily will lose from 18 to 24 per cent. of their original weight. The specialists point out, however, that it is advisable to require a minimum as well as a maximum loss which any sample may sustain. This is necessary for insuring against too much variation between the softest brick and the hardest brick which may be supplied.

The remainder of the 40-page bulletin is devoted to detailed descriptions and diagrams, showing proper methods of construction of brick roads, including the preparation of the roadbed, the con-

struction of the foundation or base, the laying of the brick, the construction of curbing, expansion cushions, and the final finishing of the pavement. The paper also includes a chapter on cost of brick pavements. Special emphasis is laid on the maintenance of these roads and the need for proper engineering supervision in their construction. An appendix is devoted to typical specifications for constructing brick roads.

The Possibilities of Developing Super-Refractory Materials for Incandescent Lighting. F. A. FAHRENWALD. (*Proceedings of the American Electrochemical Society.* September 28–30, 1916.)—It would seem to be generally conceded by electrical and illuminating engineers, that the upper limit of temperatures at which incandescent lamps may be used is fixed by the practical operating temperature of the tungsten filament. The combinations of metallic with non-metallic elements have been extensively studied, and the general properties of these compounds are well defined. No substances of this type, however, have been found satisfactory in this connection. Although the oxides of calcium, magnesium, and similar metals have found wide application in cases where heat can be applied externally, none of these can rival the tungsten filament for illuminating purposes. The conditions under which electrically heated filaments may be operated, however, allows another field to be considered—one that has as yet received little attention with this end in view—that of inter-metallic combinations.

Inter-metallic Compounds are almost invariably brittle, and such a compound if present in sufficient quantities in an alloy in which it is insoluble destroys its ductility. If a compound more refractory than either component is formed (which is a common occurrence), and if this be soluble in the more refractory component, then quite ductile refractory solid solutions are possible. Many inter-metallic compounds possess melting points several times as high as either component, which is also true of non-metallic compounds. Many of these compounds are very stable at their melting temperature if inclosed in a proper atmosphere. In many cases the melting point of a metal is lowered but very little by the solution in it of another metal, and if such a condition should accompany lowered vapor pressure, a greater thermal stability will result, thus enabling higher temperatures to be employed than are now practicable. Several series of alloys in which compounds occur that possess melting points above those of their component metals will serve as examples of the type of super-refractory compounds that may be developed by alloy research in the field of refractory metals. The mercury-sodium series is a good example, at low temperatures, of this type of alloy. Mercury melts at —38.6°C., Sodium at 97.5°C., but an alloy of the two containing these elements in the proportions represented by the formula $Na\ Hg_2$ melts at 360°C. In the zinc-tellurium series,

the compound of the formula Zn Te melts above 1200°C., while the melting points of the pure elements themselves are 421°C. and 419°C. respectively. At still higher ranges, in the nickel aluminum series, the compound Ni Al does not fuse below 1640°C. nearly 200°C. above the melting point of nickel.

It is not at all improbable that an investigation of the more refractory metallic alloys will reveal a binary series possessing a melting point curve with a maximum similar to that shown on these three typical examples. Even if this should extend only a few hundred degrees above the melting point of tungsten, the fact that the lighting efficiency does not vary directly, but as a higher power of the temperature employed, would make a material of this nature of very great value.

Melting Aluminum Chips. H. W. GILLETT and G. M. JAMES. (*U. S. Bureau of Mines,* Bulletin No. 108, October, 1916.)—The recovery of metallic aluminum in melting down chips such as are obtained in the automobile factories in machining aluminum castings commonly amounts to only 60 per cent. of the metal available, and as a 90 per cent. recovery is commercially possible, the preventable loss is of considerable magnitude. The main cause for low recoveries is apparently the difficulty of getting the tiny globules of molten metal, resulting from the fusion of the very fine chips, to coalesce when covered with oxide and dirt. As, on an average, 15 per cent. of the weight of aluminum castings for automobiles is machined off as chips, the possible saving to the automobile manufacturer is much greater than the cost of adopting careful methods of recovery.

Two methods of melting can be successfully used to promote coalescence. In one method the chips are kept just above the fusion point and the globules are made to coalesce by hand puddling, which breaks through the skin and makes the globules unite. In this method, the melting is best done in an iron pot heated by oil. The other is by the use of a flux to dissolve off the skin of dirt and oxide, producing clean globules which can unite. The flux suggested is 85 per cent. common salt, and 15 per cent. fluorspar used in large amount (20 to 30 per cent. of the weight of the chips) and mixed with the chips before charging. Much higher temperatures are required by this method than by the puddling method, so the iron pot furnace is not practicable and melting is best done in graphite crucibles or in a reverberatory furnace. The flux method does not require the constant hand puddling of the other method.

Rectangular Gas Mains. C. N. GREEN. (*American Gas Light Journal.* Vol. CV. No. 17. October 23, 1916.)—During Rapid Transit subway construction, and the attendant restoration of subsurface structures in New York City, one of the many interesting problems encountered, taxing the skill and ingenuity of the designer,

has been the restoration of pipe lines within the restricted space remaining available. In the Southern Boulevard, Bronx Borough, the Subway passes under the Port Morris Branch of the N. Y. C. & H. R. R. R. with no room for pipes between the subway roof and the railroad tracks. The railroad tracks are depressed and the Southern Boulevard crosses them on a bridge made of 24-inch I-beams and buckle plates. The buckle plates are laid on the top flange of the I-beams and support the street. There were not sufficient spaces between the I-beams to permit of manifolding the gas mains, and the distance from the street surface to the under side of the bridge would not permit the full sized main to be restored.

The gas mains were respectively 20 and 30 inches in diameter. Steel boxes were designed, one 16 x 21 inches in rectangular section, and the other 16 x 43½ inches, inside dimensions. The boxes were made of ½ inch plates riveted to ½ inch angles at the corner of the box; the angles were placed inside the box. Splices were lap riveted and all joints were caulked inside and outside. A special section was made which is rectangular at one end to fit the box and at the other end round to fit the bell of the regular main. The larger box is stiffened with a longitudinal I-beam to carry the street load. Both boxes were surrounded with concrete to reduce the possible leakage of gas to a minimum.

Humane Furnace Stoking. ANON. (*Power*, Vol. 44, No. 16. October 17, 1916.)—When a power plant is laid out for a building, the boilers and engines are frequently put in almost anywhere that they will fit, and apparently no thought is given to the probable working conditions of the men who will be employed to operate them. Frequently the furnaces are equipped with mechanical stokers, and the firemen are made to throw the coal from the floor into the hoppers—a man-killing job to say the least. In a large power plant visited recently, the furnaces of the boilers were hand fired, burning buckwheat fuel. The grates were twelve feet long, requiring a man of very ample strength to cover them. Every ounce of coal burned under these large boilers had to be shoveled into the furnace from piles in the boiler-room floor, the supply coming from an overhead bin. Towards the end of the eight-hour shift the plant suffered a marked diminution in steaming capacity, the grilling labor proving more than human strength could endure.

An easy method of firing small sized anthracite coal has been adopted by the Harrisburg Light and Power Co., Harrisburg, Pa. Here the coal supply comes from an overhead bunker, but instead of being delivered in a pile on the floor, it is discharged into the hoppers. The firemen pull a lever to let down the coal, open the firing gate, and merely spread the fuel with a light hoe, operations requiring about one-tenth the normal labor necessary with the shovel. At the end of the shift the men are not exhausted, and more than that, fewer men are required in the boiler-room force.

Use of Diatomaceous Earth in Sugar Refining. ANON. (*U. S. Geological Survey Press Bulletin* No. 297, November 1916.)—Diatomaceous earth, which is made up of remains of minute aquatic plants, is a light earthy material resembling chalk or clay. The hardness, the minute size, and the angular shape of its grains make it an excellent metal-polishing agent, and heretofore it has been largely used as an abrasive in the form of polishing powders and scouring soaps. Of late, however, according to the United States Geological Survey, Department of the Interior, the uses of diatomaceous earth have been considerably extended. It is used by sugar refiners for filtering or clarifying; as an insulating packing material for safes, steam pipes, and boilers; and as a fireproof building material. In the United States it is used in the manufacture of records for talking machines. In Europe it has been used in preparing artificial fertilizers and in the manufacture of water glass, cements, artificial stone, paper, sealing wax, fireworks, papier-maché, and other articles. A total of 4593 tons of diatomaceous earth was produced and sold in the United States in 1915.

A New Size of Camera. ANON. (*Camera Craft.* vol. xxiii. No. 11, November, 1916.)—The 8 x 10 size of plate or picture has the same proportion as the 4 x 5, a proportion that is being supplanted in favor by the post card size in the latter case, and in the former will no doubt find a strong competitor in the new 7 x 11 size issued by the Eastman Kodak Company. This is perhaps the most pleasing proportion that could be given the view photographer as it is a little shorter form of the parallelogram than the popular post card size and a little longer than the 5 x 7; it is, in fact, practically midway between the two. For group work the new size is just right, while for view and landscape work the unnecessary sky space that is nearly always in evidence in the 8 x 10 print is transferred to the ends where more room is generally wanted. Best of all the new form is much better suited to upright subjects such as tall buildings and the like. In addition the picture looks larger and the particular proportion will almost invariably show either much more of the subject matter or larger images of the objects photographed than will the 8 x 10 size.

Kauri Gum Oil—New Zealands' Substitute for Gasoline. ANON. (*Scientific American,* vol. cxv. No. 19, November 4, 1916.)—A company has been organized to extract Kauri gum oil from peat taken from the swamps in the northern part of North Island, New Zealand where Kauri gum has been mined for years. Some years ago a company was formed for this purpose and machinery installed and the plant was worked for some time, but not with favorable results, since the methods adopted and the machinery installed were not well suited for the work, so it was finally given up for a time.

It is claimed that the peat yields 20 to 30 gallons per ton, of which about 25 per cent. resembles gasoline or benzine, which is being used for motor cars and launches at this time. The remainder contains some 28 different varieties of heavy oil, some of which make exceptionally good varnishing material. It is further stated that in the north of the island are found extensive beds containing much fine kauri gum particles, and rich in materials producing this kauri gum oil, as well as kauri gum that may be extracted fom the deposits.

Surface Tension Jet Recorder. ANON. (*Electrical World.* vol. 68, No. 20, November 11, 1916.)—Valdemar Poulson, the Danish scientist, has evolved an instrument the action of which is based essentially on the alteration of the surface tension of a mercury jet by direct, alternating or even high-frequency currents. In patent No. 1,198,270, two applications of the principle are shown. In one, the current in the signal circuit causes the mercury jet to be deflected and in the other, the jet is differentially broken up into separate globules by the current, and thereby is made to operate a relay in accordance with the received impulse. The apparatus consists of a jet of liquid (strong or weak electrolyte or preferably mercury or a liquid metal alloy), which while it is still coherent and not resolved into separate drops, is in contact with a substance which forms with it a system consisting of an electrolyte and an electrode through which signal currents are led by means of another electrode.

In one form a tube of glass or iron, in which is found mercury, under suitable pressure produces a jet only a fractional part of a millimeter in diameter. The still coherent part of the jet touches a piece of glass which is partly encompassed by a body of porous nature, kept moistened with a solution of caustic potash. Around the body is wound a platinum wire serving as a conductor and at the same time acting as one electrode, the mercury jet forming the other. As soon as an alteration in the potential difference between the wire and the mercury arises owing to signal currents, the coherent part of the mercury jet is altered so that the jet is bent aside. In a modified form the lower end of the tube has a moistened ring-shaped piece of bone arranged about it. Each signal current in the signal circuit causes the coherent part of the jet to vary its length. Thus during the passage of the signal currents through the signal circuits, the jet and the contact will alternately open and close the local circuit in which the latter is interposed.

PRESS OF
J. B. LIPPINCOTT COMPANY
PHILADELPHIA

INDEX TO VOL. 182.

ACHARD, F. H., A. E. KENNELLY, and A. S. DANA: Experimental researches on the skin effect in steel rails, 135
Address (Vail), 99
Administration (Bell), 659
Air brake, The vital relation of train control to the value of steam and electric railway properties (Turner), 419, 613
Alloys, New method for measuring the resistivity of molten materials: Results for certain alloys (Northrup and Sherwood), 477
ANDERTON, BENJAMIN A., and CHARLES S. REEVE: The effects of exposure on tar products, 463
Anemometer, Linear hot-wire, on some proposed electrical methods of recording gas flow in channels and pipes based on the (King), 191
AUSTIN, L. W.: Quantitative measurements at Washington, on the signals from the German radio stations at Nauen and Eilvese, 605

BATHO, CYRIL: The partition of the load in riveted joints, 553
BELL, WM. HEMPHILL: Administration: its principles and their application, 659
BOOK NOTICES:
Charnock, G. F.: Mechanical technology, 546
Kober and Hanson: Diseases of occupation and vocational hygiene, 820
Miller, Dayton C.: The science of musical sounds, 546
BRADBURY, ROBERT H.: The future of chemistry in the high school, 229
BURGESS, GEORGE K.: Some problems in physical metallurgy at the Bureau of Standards, 19

Cables, Losses in (Northrup), 1
CARTY, JOHN J.: The telephone art, 89
Century of light (Clark), 511
Chance in sanitation, Element of (Whipple), 37, 205
Chemistry in the high school, Future of (Bradbury), 229
CLARK, WALTON: A century of light, 511
Coal, powdered, The use of, in metallurgical purposes (Gadd), 323
Column supports, Subsidence of (Eddy), 761
Condensation pump (Langmuir), 719
CREIGHTON, H. J. M.: Electrolytic dissociation in non-aqueous solutions, 745
CURRENT TOPICS: 18, 35, 36, 60, 67, 68, 101, 102, 116, 125, 126, 190, 204, 227, 228, 247, 248, 259, 260, 266, 270, 275, 276, 394, 406, 409, 410, 414, 415, 476, 510, 527, 528, 533, 534, 536, 549, 604, 611, 658, 696, 707, 718, 744, 760, 770, 790, 802, 810, 822

DANA, A. S., A. E. KENNELLY and F. H. ACHARD: Experimental researches on the skin effect in steel rails, 135
Dissociation, Electrolytic, in non-aqueous solutions (Creighton), 745

Eastman Kodak Company, Research Laboratory, Notes, 115, 531, 697
EDDY, HENRY T.: Slab deflections and subsidence of column supports in a floor test of International Hall, Chicago, made September, 1913, 761
Elements, Essential attributes of the (Richards), 78
Elliott Cresson Medal, Presentation of the, 69
ELMENDORF, ARMIN: Stresses in impact, 771
Exposure, Effects of, on tar products (Reeve and Anderton), 463

Filter, paper pulp, Note on the applicability of the (Jodidi), 61
Floor test of International Hall, Chicago (Eddy), 761
FRANKLIN INSTITUTE:
Library notes, 122, 273, 411, 544, 703, 816
Membership notes, 117, 271, 543, 702, 815
Science and the Arts Committee, Proceedings: June 7, 1916, 117; September 6, 1916, 543; October

4, 1916, 700; November 1, 1916, 813
Sections, Proceedings of Meetings: 701, 814
Stated Meeting, Proceedings: October 18, 1916, 699; November 15, 1916, 813
Franklin medal, Presentation of the, 69

GADD, C. J.: The use of powdered coal in metallurgical purposes: a discussion of the engineering principles involved, 323
Gas flow, On some proposed electrical methods of recording (King), 191
General Electric Company Research Laboratory Notes, 403, 535
German radio stations, Quantitative measurements at Washington on the signals from the (Austin), 605

Henrici harmonic analyzer (Miller), 285
Horowitz, B. Victor Meyer—his life and work, 363

Illumination, A century of light (Clark), 511
Impact, Stresses in (Elmendorf), 771
International Hall, Chicago; Slab deflection and subsidence of column supports in a floor test of (Eddy), 761

JODIDI, S. L.: Note on the applicability of the paper pulp filter to the separation of solids and liquids, 61

KELLER, HARRY F.: Sir William Ramsay: Biographical note, 267
KENNELLY, A. E., F. H. ACHARD and A. S. DANA: Experimental researches on the skin effect in steel rails, 135
KING, LOUIS VESSOT: On some proposed electrical methods of recording gas flow in channels and pipes based on the linear hot-wire anemometer, 191

LANGMUIR, IRVING: The condensation pump. An improved form of high vacuum pump, 719
Load, Partition of, in riveted joints (Batho), 553

Metallurgical processes, The use of powdered coal in (Gadd), 323
Metallurgy, Physical, Some problems in (Burgess), 19
Meyer, Victor, his life and work (Horowitz), 363
MILLER, DAYTON C.: The Henrici harmonic analyzer and devices for extending and facilitating its use, 285
Molten materials, Resistivity of, New method for measuring the (Northrup and Sherwood), 477

National department of public works: our nation's need (Randolph), 791
Nela Research Laboratory, Notes, 111, 261, 407, 529, 693
NORTHRUP, EDWIN F.: Losses in cables at high frequencies, 1
NORTHRUP, EDWIN F., and R. G. SHERWOOD: New method for measuring the resistivity of molten materials: Results for certain alloys, 477

Public works, A national department of (Randolph), 791
Publications received, 124, 275, 413, 548, 706, 821
Pump, vacuum, The condensation pump (Langmuir), 719

Radio telegraphy, Quantitative measurements at Washington on the signals from the German radio stations at Nauen and Eilvese (Austin), 605
Railway properties, steam and electric, The vital relation of train control to the value of (Turner), 419, 613
RANDOLPH, ISHAM: A national department of public works: our nation's need, 791
RAMSAY, SIR WILLIAM: Biographical note (Keller), 267
REEVE, CHARLES S., and BENJAMIN A. ANDERTON: The effects of exposure on tar products, 463
Research, Scientific, in relation to the industries (Steinmetz), 711
Resistivity of molten materials, New method for measuring (Northrup and Sherwood), 477
RICHARDS, THEODORE W.: The essential attributes of the elements, 78
Riveted joints, The partition of the load in (Batho), 553

Sanitation, Element of chance in (Whipple), 37, 205
Scientific research in relation to the industries (Steinmetz), 711
SHERWOOD, R. G., and EDWIN F. NORTHRUP: New method for measuring the resistivity of molten materials, 477
Skin effect in steel rails, Experimental researches on the (Kennelly, Achard and Dana), 135
Slab deflections and subsidence of column supports (Eddy), 761
Solenoid, Constant of a, Determination of the (Williams), 353
Solutions, Non-aqueous, Electrolytic dissociation in (Creighton), 745
Sound, The Henrici harmonic analyzer (Miller), 285
Steel rails, Experimental researches on the skin effect in (Kennelly, Achard and Dana), 135
STEINMETZ, CHARLES P.: Scientific research in relation to the industries, 711
Stresses in impact (Elmendorf), 771
Tar products, Effects of exposure on (Reeve and Anderton), 463
Telephone art (Carty), 89
Train control, The vital relation of, to the value of steam and electric railway properties (Turner), 419, 613
TURNER, WALTER V.: Vital relation of train control to the value of steam and electric railway properties, 419, 613

U. S. Bureau of Standards, Notes, 103, 249, 395, 525, 681, 803
U. S. Bureau of Standards, Some problems in physical metallurgy at the (Burgess), 19
United Gas Improvement Company, Physical Laboratory, Notes, 537, 811

VAIL, THEODORE N.: Address, 99

WHIPPLE, GEORGE C.: The element of chance in sanitation, 37
WILLIAMS, S. R.: The determination of the constant of a solenoid, 353

THE FRANKLIN INSTITUTE

ANNOUNCEMENTS

MEETINGS

COMMITTEE ON SCIENCE AND THE ARTS. First Wednesday of each month, 8 P.M. (except July and August).

BOARD OF MANAGERS. Second Wednesday of each month, 3.30 P.M.

INSTITUTE. Third Wednesday of each month (except June, July, August and September), 8 P.M.

SECTION MEETINGS. Thursday Evenings (except week of Institute Meeting), 8 o'clock. October 1 to April 30.

	PAGE
Officers for 1916	xii
Membership	xiii
Awards and Premiums	xiv
Elliott Cresson Medal	xv
John Scott Legacy, Medal and Premium	xvi
Boyden Premium	xvii
Potts and Longstreth Medals	xviii
Library	iv, xix
Journal and Indices	xix
School of Mechanic Arts	xx

CHANGES OF ADDRESS

Members are particularly requested to inform the Secretary of changes of address.

OFFICERS FOR 1916

PRESIDENT	WALTON CLARK
VICE-PRESIDENTS	HENRY HOWSON
	COLEMAN SELLERS, JR.
	LOUIS E. LEVY
SECRETARY	R. B. OWENS
TREASURER	CYRUS BORGNER

BOARD OF MANAGERS

FRANCIS T. CHAMBERS	HARRY F. KELLER
CHARLES E. BONINE	ROBERT W. LESLEY
CHARLES DAY	MARSHALL S. MORGAN
KERN DODGE	EDW. V. MCCAFFREY
W. C. L. EGLIN	RICHARD WALN MEIRS
WALTON FORSTALL	ISAAC NORRIS, JR.
ALFRED W. GIBBS	LAWRENCE T. PAUL
EDWARD GOLDSMITH	R. S. PERRY
ALFRED C. HARRISON	ALEXANDER P. ROBINSON
GEORGE R. HENDERSON	JAMES S. ROGERS
CHARLES A. HEXAMER	GEO. D. ROSENGARTEN
GEORGE A. HOADLEY	E. H. SANBORN

WILLIAM C. WETHERILL

BOARD OF TRUSTEES

JOSEPH C. FRALEY, President

WILLIAM L. AUSTIN	JOHN GRIBBEL
CHARLES A. BRINLEY	ALFRED C. HARRISON
WALTON CLARK	FREDERICK ROSENGARTEN

The Board of Trustees was formed in accordance with the following By-Laws passed in the year 1887:

> All Real and Personal Estate of the Institute which may hereafter be acquired by voluntary subscription or devise, bequest, donation, or in any way other than through its own earnings or by investment of its own funds, saving where the donors shall expressly provide to the contrary, shall be taken as acquired upon the condition that the same shall be vested in a Board of Trustees, who shall be appointed in the manner hereinafter indicated. Unless the title to such property shall be directly vested in said Board of Trustees by the donors, the Institute, by deed attested by the President and Secretary, which they are hereby authorized to execute and deliver, shall forthwith convey the same to said Trustees, who shall hold it in trust for the purposes specifically designated by the donors; or, if there shall be no specific designation, for the benefit of the Institute in the way and manner hereinafter provided, so that the same shall not, in any event, be liable for the debts of the Institute.

This method of separating the *body holding* the principal of the various funds from the Board of Managers, the *spending body*, is an original idea of The Franklin Institute and it is hoped it will appeal to friends who may desire to create funds to further the objects of the Institute, and the various branches of science in which they may be interested.

MEMBERSHIP.

Terms and Privileges.

THE MEMBERSHIP OF THE INSTITUTE is divided into the following classes, viz.: *Resident Members, Stockholders, Life Members, Permanent Members, Non-resident and Associate Members.*

Any one interested in the purposes and objects of The Institute and expressing a willingness to further the same may become a member when proposed by a member in good standing and elected by the Board of Managers.

TERMS.—Resident members pay Fifteen Dollars each year. The payment of Two Hundred Dollars in any one year secures Life Membership, with exemption from annual dues.

STOCK.—Second-class stockholders pay an annual tax of Twelve Dollars per share, and the holder of one share is entitled by such payment to the privileges of membership.

PRIVILEGES.—Each contributing member (including non-residents) and adult holder of second-class stock is entitled to participate in the meetings of The Institute, to use the Library and Reading Room, to vote at the Annual Election for officers, to receive tickets to the lectures for himself and friend, to attend the Section meetings and to receive one copy of the JOURNAL *free* of charge, except associate members, who may not take part in elections.

PERMANENT MEMBERS.—The Board of Managers may grant to any one who shall in any one year contribute to The Institute the sum of One Thousand Dollars a permanent membership, transferable by will or otherwise.

NON-RESIDENT MEMBERS.—Newly elected members residing permanently at a distance of twenty-five miles or more from Philadelphia may be enrolled as Non-resident Members, and are required to pay an entrance fee of Five Dollars, and Five Dollars annually. Non-resident Life Membership, $75.00.

Contributing members, if eligible, under the non-resident clause, on making request therefor, may be transferred to the non-resident class by vote of the Board of Managers, and are required to pay Five Dollars annually.

ASSOCIATE MEMBERS.—Associate members are accorded all the privileges of The Institute, except the right to vote or hold office, upon the payment of annual dues of Five Dollars. This class of membership is limited to persons between the ages of seventeen and twenty-five years. Upon reaching the age limit they become eligible to the other classes of membership.

RESIGNATIONS *must be made in writing, and dues must be paid to the date of resignation.*

For further information and membership application blanks address the SECRETARY of THE INSTITUTE.